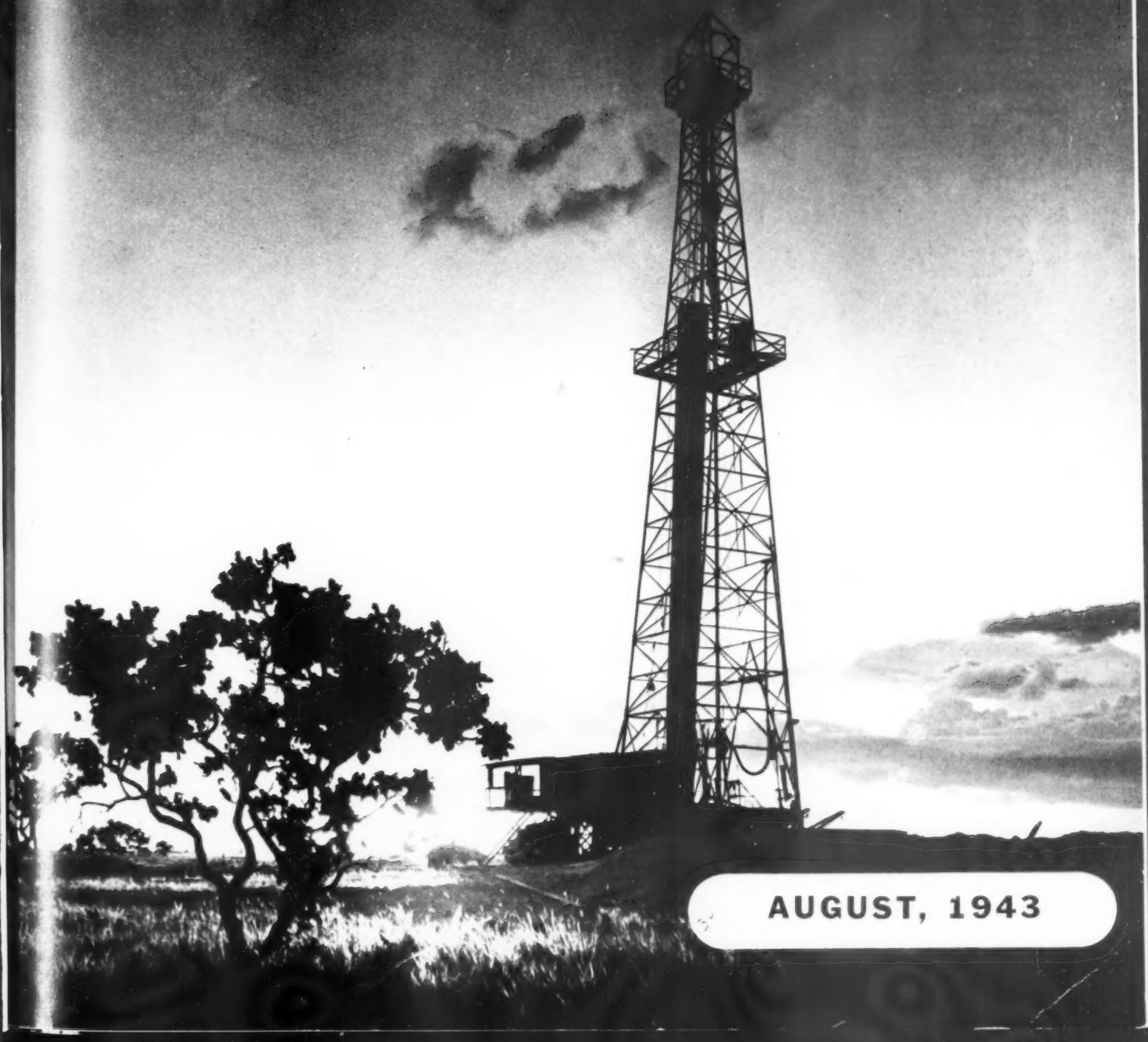
# WORLD PETROLEUM



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# WORLD PETROLEUM

*Founded by Russell Palmer*

INCORPORATING PETROLEUM EQUIPMENT EXPORTER

THE MANAGEMENT PUBLICATION OF THE INTERNATIONAL PETROLEUM INDUSTRY

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*Towers at the Phillips Petroleum Company's refinery.*

# EDITORIAL

## WAR NEEDS CALL FOR USE OF WORLD OIL SUPPLIES

DURING the early stages of the war the exigencies of the situation made it necessary for the nations combatting Totalitarianism to depend mainly upon the United States for the petroleum products essential to their operations. This country's huge production, exceeding that of all the rest of the world, made it the most available source of large-volume supplies. It alone was in a position to expand with great rapidity the output of aviation fuel which has come to be recognized as the fundamental factor in a successful offensive. U-boat depredations against shipping made it imperative to conserve tonnage and to transport troops and supplies in slow moving convoys, thereby requiring more bottoms to provide a given amount of transportation than normally would have been the case.

These conditions necessitated the movement of petroleum products for use in the European theatre of war from the eastern seaboard of the United States to the greatest extent possible. They forced a virtual suspension of shipments from the Caribbean area and required the transfer of the great American coastwise fleet to trans-Atlantic service which in turn compelled a reorganization of facilities for overland movement of oil within the country and drastic curtailment of civilian use in eastern states.

As pointed out in an article appearing on other pages of this issue this situation is now radically changed. Allied successes in opening the Mediterranean to unopposed transit by their vessels and subsidence of the submarine menace in the Atlantic have made it possible to look to other sources of petroleum supply and permit consideration of a readjustment of transportation facilities. Long before these two developments took place the military authorities, working through their own organizations and assisted by other government agencies, were formulating plans for supplementing liquid fuel supplies from the United States by drawing on other fields as these might become available. Two areas that obviously suggest themselves in light of recent changes in the military situation are the Caribbean and the Near East both of which have possibilities of substantially enlarged production and possess refining facilities for transforming crude into needed products. These are the territories that will be called upon first while studies continue of other possibilities in other parts of the world that may be of future usefulness.

As the scope of Allied operations in both hemispheres broadened and as oil's decisive part in the world conflict came to be better understood requirements of petroleum products multiplied five, ten, fifty and in some cases even a hundredfold. It came to be realized by military authorities and by the Office of Petroleum Administration which was the official body most fully informed on the oil situation that with exploration and development held in check a point would be reached where production from this country's existing facilities would no longer be able to satisfy these growing demands without serious impairment of its fields or a dislocation of its internal economy that would greatly diminish its ability to maintain production of other needed war materials. Unfortunately this realization was not shared by the Office of Price Administration, the one agency that controlled the primary incentive to expanded production, and was only tardily recognized by the War Production Board which governed the allotment of materials for drilling. The former stubbornly refused to heed the warnings repeatedly given that by holding the price of oil to the pre-war level while every item of cost had sharply risen it was preventing exploration on the scale necessary to support increased production, while the latter rested until recently on the comfortable assurance that there was plenty of oil to be had without seeking to extend existing fields.

This aspect of the situation has been highlighted in the conclusions reported by the conservative Economics Committee of the Petroleum Industry War Council as the result of a careful study conducted by its subcommittee. Among the salient points set forth in these conclusions are the following:

"For 1944 and 1945 the oil fields of the United States should not be counted on to produce without waste more than 4,200,000 to 4,300,000 barrels of crude oil per day, allowing for the fact that part of our reserves are today inaccessible to the market. . . . These quantities could be raised if price incentives and steel allocations were promptly increased. These quantities producible would of course be higher now had it not been for the low price ceilings and high costs of finding oil which have prevailed during the past two or three years. Without such price increase the committee feels that the industry may not be able to meet increasing military demand without further curtailment of civilian consumption. . . . These facts all point to the vital necessity for an immediate and continuing study of all sources of oil supply available to the United Nations in the various areas of crude oil production throughout the world, to the end that a balanced world program of supply may be developed, which will not place such a strain on the oil resources of the United States as

to impair the nation's ability to maintain adequate future levels of production or cause unnecessary expenditures of critical materials and transportation."

Petroleum products in heaviest demand for military use are aviation fuel, gasoline for motorized ground equipment, fuel oil for naval and supply vessels and lubricants. Dependence for the last named and for most of the high octane gasoline needed to assure unquestioned supremacy in the air will continue to rest in chief measure upon the United States which has developed vast and growing plant facilities for the production of this all-important super fuel. Some few installations for the production of aviation gasoline have been made in plants on both sides of the Atlantic and additions to these probably will follow as the war progresses. Ordinary gasoline and fuel oils, requirements for which already have risen above a million barrels daily, are the products which can most readily and usefully be supplied from other areas and if such sources can be drawn upon for such products to an increasing extent it will help toward relieving the serious tension now prevailing in this country. But any such relief should not be made the excuse for continuing further the blind neglect of the measures necessary to enlarge the reserves and raise the potential level of production within the United States itself. All the oil that can be found will be urgently required either during the course of the war itself or in maintaining the nation's position in the post-war world.

## POST WAR PROSPECTS OF SYNTHETIC RUBBER

One of the dramatic industrial achievements of the war has been the creation in a period of eighteen months of a great synthetic rubber industry to replace the product formerly imported from Asiatic and East Indian plantations. In this establishment of a new and independent industry the petroleum, chemical and rubber interests of the country all have had an important part but petroleum has led the way and has accepted the responsibility for providing the major part of the essential raw materials for these replacements of natural rubber. The research divisions of the oil companies have spent much time and money in perfecting the technical details of processes. The operating departments and the construction firms that serve them have labored prodigiously to design and erect the huge plants that now replace the millions of acres and hundreds of thousands of workers that formerly supplied the rubber needs of the country.

Thus far the production of synthetic substitutes for rubber is purely a war emergency undertaking. But what of the future? Are the hundreds of millions of dollars that have gone into the provision of facilities for producing nearly a million tons of synthetic rubber yearly to be written off as part of the cost of the war? Will the United States return to the payment of $300,000,000 yearly to import its rubber supplies from half way round the world? Or will the new products and the new plants producing them justify their creation commercially and be maintained as a means of freeing the nation from dependence upon foreign lands for this highly important commodity and avoiding a repetition in future of the near disaster from which we have just found a means of escape? And if synthetic production is maintained what will be its relation to the petroleum industry?

It is easier to ask these questions than to answer them, not so much because of any technical or commercial difficulties confronting the new industry as because of the fact that matters of international politics, governmental policy and trade relations are involved. With few exceptions the plants that have been built are the property of the government and political rather than commercial considerations may determine its decision as to their fate. Other possibilities yet to be determined may affect the outcome. It is conceivable that the Japanese, when finally forced to relinquish their hold upon the rubber plantations which they now control will destroy them so completely that years will be required for their restoration. It is possible that sources and processes of synthetic production will be so cheapened and improved that it will be as ridiculous to return to dependence on the natural product as it would be to revive the stage coach and ox-cart as means of transport.

One thing can be said with a good deal of positiveness. There are certain kinds of synthetic rubbers which are here to stay in any event, because they can render services for which natural rubber is less efficient and will not be accepted regardless of price. Among the new products that have now become indispensable are neoprene, hycar, ameripol, the thiokols and a number of others. The list probably will be greatly extended in the near future. Some of these products were invented and were commercially exploited a rather long time before supplies of natural rubber were shut off, and were already meeting a growing success at prices substantially above the price of natural rubber. The synthetic products above referred to have permanently established themselves in all fields of use requiring ability to withstand the action of heat, greases, oils and solvents; to resist the action of air and sunlight; to absorb vibrations, and to stand abrasion and wear.

The question of whether a synthetic rubber industry will survive into the post-war era thus narrows down largely to the question of whether Buna S can survive a restored competition with natural rubber in the manufacture of tires. As President Roosevelt might say, this question is largely "iffy." In the first place, it will have to be determined whether competition is to be restored. Certain hints have been dropped from high quarters that, as a matter of public policy, the post-war domestic market might be rigged against the synthetic product in favor of the natural product. This policy, if adopted, would have for its purpose the preservation of an outlet for the foreign producers of natural rubber, so that the latter might continue to absorb the products of American exporters. It would be presented as a demonstration of the policy of live and let live that has been expressed more or less definitely in the economic clauses of the Atlantic Charter. In that case the American facilities for the emergency production of Buna S would be scrapped along with other agencies that are needed solely for war purposes, except that some stand-by facilities might be retained as an insurance against the

gouging which the foreign producers have occasionally practiced.

Assuming that a good neighbor policy involving such an extent of self sacrifice does not prevail, and that Buna S will be left free to contend against all comers in an open market, its battle will be won or lost on the question of price. It has been said that with a capping of a synthetic rubber that has a high resistance to wear, an automobile tire might be good for 100,000 miles and thus outlast the normal life of the average car, which might become true also of a tire the body of which is made of natural rubber. This defines the field of competition between the two products, and it becomes a question as to which is the cheaper, all things considered.

When events necessitated inauguration of the synthetic rubber program it was generally thought that Buna S could be produced at a cost of 25 cents a pound. Since then the processes are said to have been improved so that it may not cost more than 16 cents. Hopes have been expressed that the cost may be lowered still further, but if the hoped-for progress does not materialize and the cost remains 16 cents, the producers of natural rubber will probably be able to under bid. In 1933, before restraint was put on native producers not heretofore included in the rubber cartel of the European-owned plantations, crude rubber sold at three cents a pound. This was a sacrificial figure but it indicates something of the price range within which oriental labor might be willing to compete. Against such competition American-produced Buna S would not have a chance except under two possible conditions; one condition is that present processes must be drastically cheapened; the other is that tariff protection be raised against foreign natural rubber. Against the possibility that the American producers of Buna S may improve their processes, which may require time, there is the possibility that the experiment stations devoted to improvement of the rubber plant may in time find new varieties that give higher yields. The geneticists of these stations, have in the past accomplished much in this direction. A high protective tariff would take care of that, provided that the good neighbor policy above referred to did not intervene to preserve the livings of the Oriental producers.

Assuming either that Buna S can maintain itself competitively, or that it is provided with sufficient tariff protection, there will remain the question as to what segment of American industry shall be allowed to supply the raw material for its manufacture. This raw material is mostly butadiene, which may be had from two very different sources: grain or sugars, or hydrocarbons including acetylene. Butadiene from both these sources is currently employed to make a wartime supply of Buna S, and under present circumstances costs are secondary matters because synthetic rubber must be obtained regardless of price. But when peace comes the rubber manufacturers will be governed by the price situation. Admittedly, production of butadiene from grain, or even from cheap molasses, costs considerably more than from certain petroleum products, as for instance when normal butane, which occurs abundantly in natural gas, is dehydrogenated in a single pass through a bed of a new Houdry catalyst. But again there arises a possible question of public policy. If it should be necessary to lay a tariff against natural rubber the agricultural interests may insist that it be made high enough to permit the use of farm products, along with a provision compelling the rubber manufacturers to use more or less of butadiene made from such products. The probability that such a public policy would be adopted may seem remote. That the possibility exists is indicated by the persistent efforts of the agricultural interests to enforce the mixture of alcohol with gasoline to produce automobile fuel, and by the pressure they applied to force the inclusion of alcohol in the butadiene program.

Other possibilities must be taken into account. Before natural rubber has an opportunity to regain its former place most of the cars in America will be rolling on synthetic tires and tubes. Manifold other uses of rubber will be served by synthetic products. If they serve their users well, if they display higher efficiency and better lasting quality than the products they have displaced, the American public is not likely to acquiesce quietly in the scrapping of a great industry built with their funds. They will not willingly submit to the manipulations of a foreign cartel controlling a material on which their whole industrial economy is based. Nor will they wish to risk again the possibility of being deprived of their most essential means of transportation. The influence of this factor remains to be determined by future experience but it may very well prove to be decisive.

If this large scale test satisfies the motoring public of the inherent superiority of the synthetic product, if no adverse public policy intervenes and if price competition can be met American produced Buna S probably will continue to be made either from normal butane or from the butylene that is produced as a by-product in petroleum refining by catalytic processes.

Whether the tires and other rubber products of the future are derived from petroleum, from grains or molasses via the alcohol route or from hevea, guayule or kolsagyz actually is of small moment to the oil industry so long as quantity and quality suffice to keep millions of cars moving over the world's highways. Contrary to allegations made during the somewhat heated discussion over the most suitable source of synthetic materials, when some overzealous partisans of grain alcohol accused the oil companies of seeking to monopolize rubber manufacture, their actual purpose, as has been amply demonstrated, is to avoid being drawn into a field of endeavor so far removed from their regular line of business. If all the raw material for all the synthetic rubber used in the country were obtained from petroleum it would represent but six-tenths of one percent of their annual trade volume. As a market for petroleum products synthetic rubber is relatively negligible.

On the other hand the oil industry has a tremendous stake in seeing that the people are abundantly supplied with cheap and durable rubber for all the motor vehicles they can use, for therein lies its great and profitable market for gasoline and lubricants. If rubber substitutes meet these requirements better than natural rubber the petroleum industry will favor their continued use and so will millions of others not connected with that industry. In other words the future of the synthetic rubber industry, so far as can be foreseen, very likely will rest with the men who have given it an auspicious start. In any event, whatever happens to Buna S, a synthetic rubber industry for the making of products which already have demonstrated their superiority unquestionably is here to stay.

*Making the final weld marking the completion of 1381 miles of pipeline from Texas to Pennsylvania.*

# WAR EMERGENCY PIPE LINE COMPLETED TO THE EAST

## World's Greatest Oil Duct With Capacity of 300,000 Barrels Daily Built Across Country From Texas to Atlantic Coast in 350 Days

TAKING its place among the noteworthy forward steps in the march toward victory the formal ceremony marking the completion of the War Emergency Pipe Line was held on July 19 in a field surrounded by wooded hills, a few miles from Phoenixville, Pennsylvania. In an open ditch close to one of the pump stations that will supply the power to keep a veritable river of oil rolling eastward across the country two of the great forty-foot sections of pipe lay ready for the final connection. In the presence of leading representatives of the oil industry, government officials and some few of the men who had labored prodigiously to make the giant line a reality, two expert welders pulled their protecting hoods over their faces, applied their electric torches and burned the final bead that marked the completion of 1381 miles of continuous line from Texas to within hailing distance of the Atlantic Coast. It was exactly like 200,000 other welds that had punctuated the steady progress of pipe laying over mountains, under rivers, across more than half

*Petroleum Administrator Harold L. Ickes broadcasting his address on the formal completion of the Big Inch Line, July 19, 1943.*

many and Italy in Africa and over Europe—against Japan in the Aleutians and the South Pacific. And if will and work and the vast, expanding facilities of America's petroleum industry can prevent it the armed forces shall never run short of fighting oil.

"In the effort to insure and to increase that flow directly to our fighting men, we are faced with the necessity of producing, refining and delivering the oil for war without a definite goal to be met, a known challenge, against which to plan and gauge our efforts. We must produce increasing millions of barrels of aviation gasoline, motor fuel for trucks and mechanized battalions, fuel oils for ships and tanks, against the practically limitless demand of uncertain battle requirements. We can thus have but one goal—to produce and deliver more and more and more, in the savage hope that all of the oil that we can provide will be enough—enough to assure that every plane, every ship, every tank and gun and convoy can fight through at full striking power, any time, and every time, that the order comes—'Attack!'

"This 'must' that we face, this challenge to supply the armed forces with oil in an endless bridge of ships makes the policy of assuring that supply

the breadth of the continent. It was the work of a few moments but its significance in sealing the victory of brain and brawn over time and weather and difficult natural barriers assured the two welders, Bart Wakefield and Ray Quinn, a place in the pipeliner's hall of fame.

It was a proud day for Petroleum Administrator Harold L. Ickes who had proposed the building of the line three years before, on July 20, 1940, had fought it through to final authorization by the War Production Board on June 10, 1942, and had put the full force of the Petroleum Administration behind the effort needed to assure its rapid completion. Modestly minimizing his own part in the great enterprise he paid high tribute to the men who wrought the work in presenting a citation to the President of War Emergency Pipelines Inc. in recognition of their valiant teamwork and in the brief address which he had prepared for the occasion he emphasized the distinctive character of the line as an instrument for effective prosecution of the war. "Our Army and Navy," said the Petroleum Administrator, "and the forces of our Allies who necessarily depend upon America's oil for their safety and success—these have not lacked for oil—on time—the oil that has powered our initial successes against Ger-

***Right: W. Alton Jones, President of War Emergency Pipelines, Inc., on an inspection trip over the line.***

*Above: Pipe ready for shipment to various points along the right-of-way.*

*Right: One of the huge trenching machines that dug the ditch carrying the Big Inch across the country. Photo courtesy Buckeye Traction Ditcher Co.*

by every means at our command more than prudence. It becomes the only basis on which we who work so far from the blastings and the bloodletting of war can, with pride in the doing of it, send our men into battle with confidence of victory and with the conviction in our hearts that we have given them not merely adequate—not merely ample— but *all* of the petroleum that they need to fight and win this mechanized war.

"We delay their victory, for freedom and for us, we bury more American boys abroad and beneath the waves, when we deny them one gallon of the oil that they need. But we can and so we must assure that victory—assure it by a still more extensive and vigorous mobilization of the oil industry for the task—assure it by a still more effective coordination of the job by the government—assure it, above all, by the personal, individual collaboration of every single citizen, not simply to save gasoline and oil, but to stop its use for any purpose that does not add directly to the fighting power of this Nation.

"Without that cooperation every other effort is shackled. We can assure victory by such instruments of war as this great pipeline—this super artery for the fighting strength that is impotent in the wells of Texas but invincible when delivered, via the eastern seaboard, to the machines of war across the Atlantic. In the flush of present victories let us not abandon the resolve by which they have been won. Let us not, in the knowledge that the 'Big Inch' is ready to flow new quantities of oil into the East, plead for an increase in pleasure driving at the expense of an increase in the power of our attack. Our conveniences and petty comforts are expendable. Our self-denial is more than patriotic sacrifice. The oil shortage that you and I know as individuals is a positive factor in the strength of our fighting men.

"We have pledged, as a Nation, our every resource, to the end that the legions of inhumanity shall be brought to their knees in unconditional surrender. That is the common pledge of all men and all Nations who stand today under arms for freedom. We owe to them, as brothers in the fight, no less than all of the power that the 'arsenal of Democracy' can produce for the common victory. And so today, conscious deeply of our gratitude to you, W. Alton Jones, to your fellow-directors of War Emergency Pipelines, to all of your colleagues of the petroleum industry who are fighting the battle of oil transportation, and to every man and woman whose skill and sweat have brought this 'Big Inch' to reality, we flex the muscles of our fighting might and add to the stature of our resolve unto victory, by dedicating this 'Big Inch' oil artery to the sole task that inspires all honest men in this hour of Armageddon—the task of victory for the freedom of all men."

It was a day of great satisfaction for W. Alton

*Right: Despite extreme weather conditions, work on the Big Inch progressed rapidly.*

*Left: Over hills, through valleys, across rivers, the Big Inch wends its way Eastward.*

(Pete) Jones, president of War Emergency Pipelines Inc., for General Manager Burt Hull and Major Al Horne who directed the construction of the line from start to finish, for Captain W. R. Finney who chairmanned the engineers who designed it and for thousands of other workers who could not be present but whose labors had contributed to the speedy completion of a difficult and giant task. Their satisfaction stemmed from the fact that the big job had been put through on time—a bit ahead of time in fact—exactly 350 days from the date on which the first weld was made on the world's longest string of pipe, on August 3, 1942.

Since the line was built with public funds and is owned by a government agency, Defense Plants Corporation, it is worth recording that the performance in building the line is regarded as deserving of praise by those who carried the financial responsibility, that they feel that it has been well and economically constructed and represents an investment distinctly worth while. Charles B. Henderson, who represented Secretary Jesse Jones, chairman of the present Reconstruction Finance Corporation, at the completion ceremony made special mention of the fact that the cost of the line was $5,000,000 less than the advance estimate. In the message transmitted to the gathering through Mr. Henderson, Secretary Jones also called attention to the fact that every pipeline contractor in the country with equipment heavy enough to handle pipe of the size and weight required for the huge line had shared in the work of construction and quoted the statement of company officials that each of them had spent the government's money as economically and as efficiently as though it had been his own.

Central figure in the simple ceremonies that marked the completion of the Big Inch line, as he has been in dealing with the manifold problems and difficulties that have attended the change over of American oil transportation from deep water routes to a land based system, was W. Alton Jones, president of War Emergency Pipelines Inc., chairman of the National Transportation Committee and the Pipeline Management Committee of the Petroleum Industry War Council, in addition to being the executive head of Cities Service Company. Forceful, vigorous, exacting, affable and highly competent, Mr. Jones brought to his trying task the rare combination of qualities needed to overcome difficulties and delays, to surmount unexpected obstacles and to maintain the spirit of enthusiastic determination that has characterized every step toward realization of the great project and has inspired the thousands of workers who have participated in the undertaking. His response to the congratulatory words of the Petroleum Administrator and other speakers was typically brief and to the point, directing attention to the fact that the petroleum industry was on the threshold of transferring more oil to the East than ever had been moved into that area before and that the pipe lines now adding to this expanding movement would serve the public well.

From the time when the go-ahead signal was given for construction of the Big Inch through authorization by the War Production Board of use of the necessary materials pipeline records began to fall. The approval granted on June 10, 1942 applied only to the first leg of the projected line, from Longview, Texas, to Norris City, Illinois, a distance of 531 miles. The engineering plans and surveys had been completed, the organization had been tentatively set up and was ready to function and the cost of the undertaking, estimated at $35,000,000 was promptly underwritten by Defense Plants Corporation. Within two days after official sanction had been given an order had been placed with National Tube Company, subsidiary of United States Steel Corporation, for approximately 550 miles of 24-inch seamless steel pipe. By the end of one month fifteen contracts for digging the ditch and laying pipe had been concluded. On July 18 the first trainload of pipe was shipped and at the conclusion of fifty-four days pipe had been strung along a considerable section of the right-of-way and the work of welding was under way.

Owing to the unusual size of the pipe to be handled construction equipment had to be redesigned or fitted with special attachments. Stringing trucks, ditching machines, and winches had to be adjusted to the heavier weight and large diameter of the pipe. These problems were quickly solved however by the veteran pipeliners who had plied their trade in many parts of the world and under all sorts of conditions. The line was pushed forward rapidly under a schedule by which all activities were coordinated with military precision; pipe stringing, right-of-way

*Above: Final tour of inspection before pipe is lowered into ditch and backfilling begins.*

*Below: Truck has encountered heavy going while working on the Eastern section of the Big Inch. Photo courtesy International Harvester Co.*

*Applying protective wrapping to the pipe. Photo courtesy The Barrett Co.*

clearing, ditching, welding, laying and backfilling followed a time table worked out so exactly that no step in the successive operations was delayed by failure to complete the one preceding on time.

Some difficult terrain was encountered on this section of the line, particularly in the swamplands of Arkansas and in the river bottoms when unseasonable floods caused some unavoidable delays. Some of the river crossings presented unexpected obstacles on account of high water and the condition of the approaches and in December a flood washed away the equipment assembled for the Mississippi crossing. But in spite of all difficulties the line was pushed rapidly forward and on the last day of the year pumping of oil into the Longview end of the line began. Delays in the delivery of pumping machinery made it impossible to equip all the stations by the time the line itself was laid and initial operations were at only part capacity.

On February 19, 1943, the first oil transported through the line was loaded into tank cars at Norris City and was sent on its way eastward, 200 days after the start of welding. By cutting more than a thousand miles off the round trip route of hundreds of tank cars moving crude and fuel oil to eastern states the volume of tank car deliveries to those areas was immediately stepped up and continued to increase as the line approached capacity operation.

Meanwhile the need of carrying the line all the way to the Atlantic Coast had become so evident that the War Production Board on October 26, 1942, had responded to the recommendations of Petroleum Administrator Ickes by authorizing the use of the needed materials for this addition to the system. The eastward extension was laid out to run from Norris City to Phoenixville, Pennsylvania, a distance of 722 miles, with branches from the eastern end to serve the refining districts of the New York Harbor area and Philadelphia. Consequently the completion of the line to Norris City caused not even a momentary pause in its eastward progress. The mills which had been turning out pipe for the first leg continued to pour it out—a train load a day—and to ship it to new delivery points from Illinois eastward. The construction gangs that had carried the line from Texas across the Mississippi moved on to tackle new spreads. The management shifted its operating staff and blue prints from Little Rock to Cincinnati and the fight to push the big line forward to the sea was on.

Building the eastward extension of the big line is admitted by pipeliners of world wide experience to have been one of the toughest jobs of their varied careers. The work was carried on during one of the severest winters in many years. It involved pushing the line over the Alleghanies, a difficult undertaking under the most favorable conditions but rendered almost impossible by the combination of ice, snow and mud encountered all along the way. Impossible, however, is a word unknown to the pipeliner's vocabulary. With the coming of spring the mountains had been conquered and the construction crews rolled swiftly and happily down the eastern slopes and through the Pennsylvania valleys to the eastern terminus. They had built the world's greatest pipe line in world record time and were ready to tackle any other job that might offer, provided it were amply spiced with danger and possibilities of trouble.

While the Big Inch line is officially rated as extending from Longview to Phoenixville, 1253 miles, because that is the actual span of 24-inch pipe, the system really embraces considerably more mileage than is covered by the main stem. At the western end it is fed by four lines extending from Houston, Beaumont and Port Arthur. At the eastern end it bisects at a point just beyond Phoenixville into two branches of 20-inch diameter each, one extending northeastward to Linden, N. J., where it connects with a network of smaller pipes conveying oil to the numerous refineries in the New York-New Jersey area. The second line, branching southeastward to Marcus Hook, Pennsylvania, similarly supplies refineries in the Philadelphia district. Including these two branches for distributing its flow, the eastern leg of the Big Inch system comprises 857 miles of pipe and its total length, not including the Texas feed lines referred to, is more than 1450 miles.

Although officially completed, oil will not begin to flow into the eastern refineries until sometime in August. The line is being filled at the rate of 100,000 barrels per day from Norris City and this oil, flowing eastward at the regulated rate of two to three miles per hour will require ten to twelve days to reach Phoenixville. Under normal conditions oil will traverse the distance from Longview to the eastern seaboard in between thirteen and fourteen days.

Superlative in so many respects that a full description of them is impossible within the space of a single magazine article, a few random facts regarding the Big Inch will bring out some interesting high lights.

The line is both the longest and largest single oil carrying system in the world. Its capacity is 300,000 barrels daily. It is also a vast underground storage system since 4,000,000 barrels of oil are required to fill it from end to end.

To move the oil over the long route from Texas to the East Coast the main line is provided with twenty-six pump stations equipped with powerful centrifugal pumps electrically driven. There are 78 main line motors operating at 1800 RPM and developing 1500 h.p. each. Total horsepower of the pumping equipment is 117,000 h.p.

Storage tanks of the system have a total capacity of approximately 5,000,000 barrels.

Approximately 360,000 tons of steel was used in the construction of the line and its auxiliary pumping, storage and terminal equipment.

The Big Inch is capable of delivering as much oil from Texas to the Atlantic Seaboard as a fleet of 50 tankers or 25,000 tank cars.

Cost of building the line was roundly $95,000,000—$35,000,000 for the wesetrn leg; $60,000,000 for the longer eastward extension.

Contracting firms who participated in the construction of the Big Inch included the following:

Anderson Bros., Tulsa, Oklahoma.
O. E. Dempsey Construction Co., Tulsa, Okla.
Bechtel-Dempsey, Zanesville, Ohio.
Exeter Construction Co., Camp Hill, Pa.
Ford, Bacon & Davis Construction Corp., N. Y.
C. S. Foreman Co., Kansas City, Mo.
I. C. Little, Dallas, Texas.
Midwestern Engineering & Construction Co., Tulsa, Okla.
Oklahoma Contracting Co., Dallas, Tex.
Sheehan Pipeline Construction Co., Tulsa, Okla.
Ray L. Smith Construction Co., El Dorado, Kan.
O. C. Whittaker Co., Ft. Worth, Tex.
Williams Bros. Corp., Tulsa, Okla.

Other phases of construction operations were handled by the following:

Geo. C. Bolz Dredging Co., St. Louis, Mississippi River crossing.
General American Transportation Corp., Sharon, Pa., erecting tanks.
Graver Tank & Mfg. Co., East Chicago, Ind., erecting tanks.
Hammond Iron Works, Warren, Pa., erecting tank.
Huey & Cage, Monroe, La., pipeline location surveys.
Lockwood, Kessler & Bartlett, Brooklyn, N. Y., pipeline location surveys.
Midland Construction Inc., Chicago, erecting pump stations.
L. E. Meyers Co., Chicago, construction of electric substations and transmission lines.
Pittsburgh-Des Moines Steel Co., Des Moines, Iowa, erecting tanks.
H. C. Price Company, Bartlesville, Okla., electric welding.
C. S. Seal, Sicily Island, La., clearing right-of-way.

(*Continued on Page* 56)

# SYNTHETIC RUBBER PROGRAM

## Moves Forward on Schedule

**By Lorania K. Francis**

**Production in First Quarter of 1944 Expected to Be Close to 200,000 tons—New Plants Coming Rapidly into Operation.**

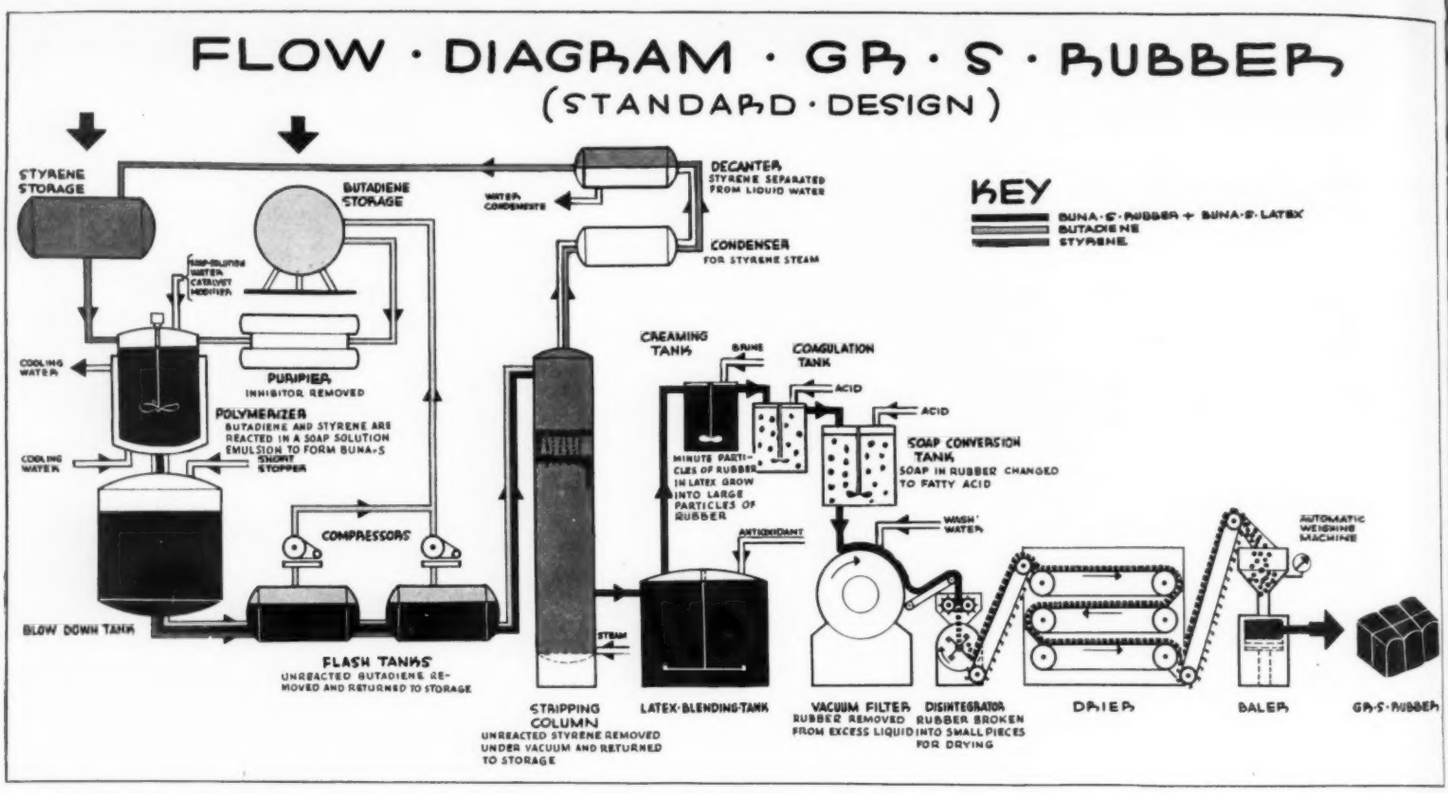
*Washington officials on their arrival to inspect the Neches Butane Products Company plant being built in southeast Texas, reading left to right: W. M. Jeffers, Rubber Director; James Forrestal, Under Secretary of the Navy; Ralph K. Davies, Deputy Administrator, PAW; Herbert Henderson, Chairman of the Board of the Neches Co.; Robert P. Patterson, Under Secretary of War; Bruce K. Brown, Asst. Deputy Administrator, PAW; C. S. Reed, President, the Lummus Company.*

AMERICA'S greatest industrial achievement, the manufacture of synthetic rubber to replace her normal supply of hundreds of thousands of tons of the natural variety coming from areas seized by Japan, is rapidly making progress to a point where military demands can be satisfied and civilians may look forward to relief from the present shortage.

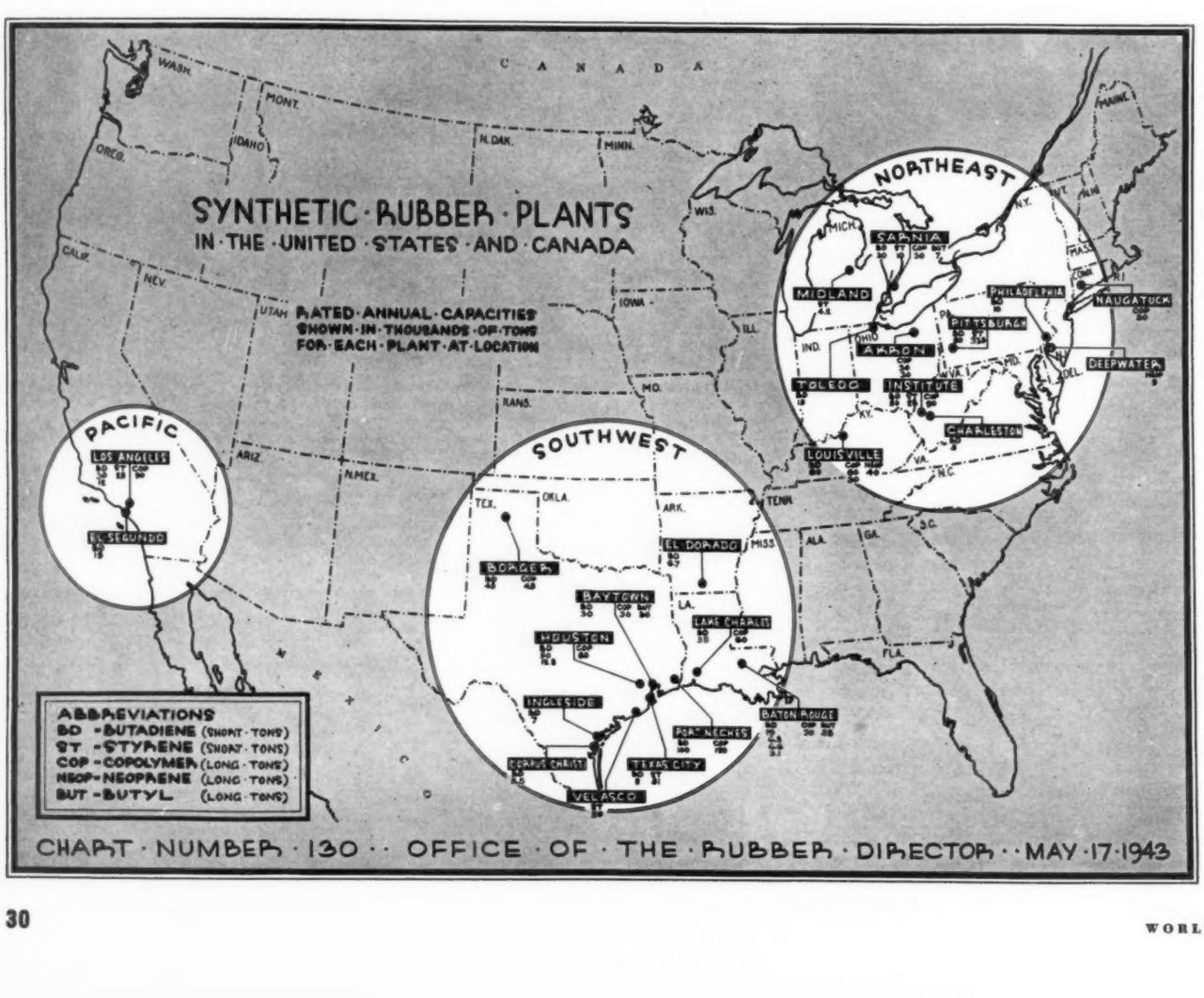
Beset with difficulties from the day the government faced the stupendous task of creating an entirely new, and almost completely artificial, source for rubber, the synthetic program seemingly is well over the hump and on the road to its announced goal of 850,000 long tons annually of the four most vitally needed elastomers—Buna S, butyl, neoprene and Buna N rubber.

While credit belongs, primarily, to three great industries—petroleum, chemical and rubber fabrication—the ability of the fledgling synthetic industry to, almost literally, "lift itself by its bootstraps" is a tribute to American ingenuity. Hundreds of small firms are helping by producing the components needed for final processing; construction engineers have performed miracles of plant conversion and have tackled entirely unexplored problems of new-plant construction; government authorities, despite differences of opinion which undoubtedly had a retarding effect on the program in its earlier stages, have buckled down to the task of turning out sufficient rubber to keep our highly-mechanized war machine rolling on the only satisfactory material so far devised for swift and shock-absorbent traction.

No one in government or industry will deny that the problem, in the early days of the war, was so appalling that, in any other country, it easily could have been counted insuperable. After this war, there will be many chemists, engineers, equipment manufacturers and government officials




[*Note*] *GRS is the official designation for the type of synthetic rubber heretofore known familiarly as Buna S.*



who will look back upon the struggles of the new synthetic rubber industry with dazed astonishment and near-disbelief.

The mighty plants, now coming into operation from week to week, and the output of as much rubber made from alcohol, petroleum and chemical products as ever came to this country from far-off plantations, will be proof, however, of how a great industrial nation mastered the "impossible".

America's greatest industrial problem has been materials with which to meet the world's most ambitious program for the production of every weapon of war. Forced by the surprise attack on Pearl Harbor to increase its war production a thousand-fold over the early defense and Lend-Lease requirements, the government found itself besieged by frantic manufacturers, demanding construction materials, rare minerals, costly equipment, intricate machine tools and all the other components of war industry.

Ships, planes, guns, tanks, vital 100 octane aviation gasoline, munitions and literally thousands of other products necessary to total victory, all needed, and all had to have, much the same materials so that the needs of each one conflicted with the requirements of all. The heavy industries, producing the basic materials going into the manufacture of the more specialized parts and equipment, already were staggering under the new demands. Imported products, such as tin, tungsten, nickel and many other components of light alloy metals desperately needed by the manufacturers, were held at their source by the increasing menace of enemy submarines.

Considering these problems, and they amount to only part of what the government was facing, with its diminishing manpower, lack of housing, inflationary price and wage trends and other war-born dilemmas—a real excuse can be found for some of the verbal fisticuffs occurring among officials, each charged with the expediting of his own program.

## Synthetic rubber plants, capacities completed June 30, 1943

| Company | Location | Rated annual capacity in operation (tons) | Date of beginning operation | Total cost [1] |
|---|---|---|---|---|
| **BUTADIENE** | | | | |
| Carbon & Carbide | Charleston | 5,000 | 1942 | [2] |
| Do | Institute | 80,000 | May 1943 | $34,900,000 |
| Do | Louisville | 20,000 | June 1943 | 24,357,000 |
| Eastern States | Houston | 12,800 | do | 3,175,000 |
| Koppers | Pittsburgh | 20,000 | do | [3] 47,845,000 |
| Phillips | Borger | 11,250 | do | 30,750,000 |
| Shell & Southern California Gas | Los Angeles | 30,000 | do | 5,332,000 |
| Standard of Louisiana | Baton Rouge | 6,600 | January 1943 | [2] |
| Do | do | 3,100 | February 1943 | [2] |
| Do | do | 15,000 | May 1943 | 9,579,325 |
| Do | do | 6,800 | March 1943 | 1,610,000 |
| | Total: | 210,550 | Total: | $157,548,325 |
| **STYRENE** | | | | |
| Carbon and Carbide | Institute | 25,000 | June 1943 | $8,399,000 |
| Dow Chemical | Midland | [4] 4,200 | April 1943 | [2] |
| Do | Los Angeles | 12,500 | May 1943 | 13,130,000 |
| Monsanto | Texas City | 20,000 | January 1943 | 16,684,400 |
| Dow Chemical of Canada | Sarnia | 10,000 | July 1943 [5] | [2] |
| | | 71,700 | | $38,213,400 |
| **COPOLYMER** | | | | |
| Copolymer Corporation | Baton Rouge | 30,000 | March 1943 | $7,450,000 |
| Firestone | Akron | 30,000 | do | 5,526,565 |
| General Tire & Rubber | Baytown | 30,000 | June 1943 | 5,625,000 |
| Goodrich | Louisville | 60,000 | May 1943 | 11,000,000 |
| Do | Port Neches | 30,000 | June 1943 | 22,706,899 |
| Goodyear | Akron | 30,000 | April 1943 | 5,825,000 |
| Do | Los Angeles | 30,000 | March 1943 | 17,000,000 |
| United States Rubber | Naugatuck | 30,000 | April 1943 | 7,075,500 |
| Do | Institute | 60,000 | June 1943 | 17,000,000 |
| | | 330,000 | | $99,208,964 |
| **BUTYL** | | | | |
| Standard of Louisiana | Baton Rouge | 7,000 | January 1943 | $21,197,400 |
| | | 7,000 | | $21,197,400 |
| **NEOPRENE** | | | | |
| Du Pont | Deepwater | 9,000 | 1942 | [2] |
| Do | Louisville | 20,000 | April 1943 | $46,000,000 |
| | | 29,000 | | $46,000,000 |
| **THIOKOL** | | | | |
| Du Pont | Deepwater | 22,000 | January 1943 | [2] |
| Private plants | | 2,900 | 1942 | [2] |
| | | 24,900 | | |
| | TOTAL: | 673,150 | TOTAL: | $362,168,089 |

[1] Defense Plant Corporation reports: N. D. 184, No. 28, Apr. 30, 1943; N. D. 183, No. 56, May 15, 1943; N. D. 183, No. 57, May 31, 1943. Cost figures are those of entire plant.
[2] No authorization.
[3] Includes cost of Koppers styrene plant.
[4] Part of 12,500 tons contracted for by Rubber Reserve.
[5] Scheduled completion date.
Office of Rubber Director, special reports staff, June 10, 1943.
NOTE.—Completion dates are those for last units only of multiunit plants.

The War Shipping Administration felt ship construction came first. The Petroleum Administration for War set up a desperate outcry when Rubber Director William M. Jeffers received a higher priority rating than PAW could get for production of the petroleum that is playing one of the mightiest parts of the war by giving America and her allies an air advantage that the Axis cannot hope to equal. All of the men who carry the full responsibility for their respective programs needed steel, valves, heat-exchangers, and hundreds of other scarce products. To give to one, it was necessary to deprive the others. This is the basic reason for the "Battle of Washington", which still flares up occasionally between the various agencies when somebody gets an AA-1 rating, or an out-and-out directive from the War Production Board, where the "rivals" receive only a rating of AA-2X . . . the rivalry, it might be pointed out, is just as great among the industries themselves, as among the official arbiters in Washington. But less is said about it.

The synthetic rubber program had rather more than its share of such difficulties, complicated in its case by the claims of various processes and the ardent advocacy by competing groups championing different products as sources of supply. The tangle that resulted led to the President's appointment of the Baruch Committee and to the comprehensive report submitted by the committee, charting a course which Rubber Director Jeffers has tenaciously followed since his appointment to his present post. While the Baruch committee's recommendation of 1,074,000 tons of synthetic rubber to be produced annually seemed a staggering figure the goal was set sufficiently high so that the present modified program of 850,000 tons will still serve to meet the essential needs of the country.

Complexities of synthetic rubber manufacture are so great, that only the large-scale operations can be dealt with in a single story.

To produce the four major types of rubber, the government has financed, or partially financed, plants producing styrene and butadiene and copolymer plants producing Buna S. It has turned over to the rubber industry the task of processing the various materials into tires, life-rafts, and all the finished products made of rubber.

The estimated total production for the four major synthetics (Buna S, Butyl, Neoprene and Buna N) will be 275,220 long tons this year, according to the Office of the Rubber Director. This

is the equivalent of 254,000 tons of the natural product.

Production, however, will take a decided jump by the early part of 1944. It is hoped, and believed, that the nation will be turning out 195,750 long tons during the first three months of next year or 45,600 tons over estimated production during the final quarter of this year.

Here are some figures that will indicate progress during the present year. In the interests of conserving space, and for purposes of real comparison, production for the first and last quarters of 1943, and projected production for the first quarter of 1944 will be used:

| | 1943 (1st Quarter) | 1943 (4th Quarter) | 1944 (1st Quarter) |
|---|---|---|---|
| Buna S ... | 3,100 (l.t.) | 126,100 | 163,000 |
| Butyl ..... | 35 | 7,650 | 14,950 |
| Neoprene .. | 4,365 | 11,000 | 12,400 |
| Buna N ... | 2,980 | 5,400 | 5,400 |

In other words, total production for the first three months of the coming year will be 195,750 long tons, as compared with a full year's (1943) production of 275,220 tons.

Production had to be cut back considerably, because of orders from WPB which were necessary for the careful distribution of critical materials. The Office of the Rubber Directory points out in its "Progress Report No. 3":

"Additional plant capacity originally recommended for the production of 109,800 short tons of butadiene; 33,600 short ons of styrene; and 140,000 long tons of copolymer (Buna S) has not been approved."

It was further noted in the report that Butyl and Neoprene will not be needed for production of military tires, and that isobutylene (used in Butyl manufacture) is critically needed in the 100 octane gasoline program. For these reasons, 64,000 tons of Butyl plant capacity and 20,000 tons of Neoprene were dropped by ORD from its program. The only recent cancellation was that of a small company working on 100 octane production, about a month ago, according to the Office of the Rubber Director. The capacity lost in this case was only 8,000 tons butadiene yearly.

Although the petroleum industry is scheduled to play probably the most important role in postwar production of synthetic rubber, about 75 percent of the plants using petroleum base stocks remain to be completed. On the other hand, the production of rubber from an alcohol base is pretty well in hand, with from 50 to 60 percent of the plants now in operation and most of the rest due for completion in a month or two.

The scarcity of equipment and the difficulty of getting deliveries is the major bottleneck in the program. Figures on the number of plants completed, nearing completion and in operation are available only from ORD's progress report charts and tables. These are as follows:

*View of Neches butadiene plant.*

Copolymer (Buna S): Under the first WPB directive, three units have been put in operation, each with a 30,000-ton capacity; one each at Institute, West Virginia, Baton Rouge, La., and Los Angeles. Six additional units have since been completed, under the second directive, as follows:

Louisville, Ky., 15,000 tons; Borger, Tex., 45,000 tons; Institute, 30,000 tons; Baytown, Tex., 30,000 tons; Port Neches, Tex., 30,000 tons; Institute, 30,000 tons.

One plant remains to be completed under the second directive. It is a 30,000-ton unit at Louisville. The five units, not yet completed, are scheduled under an AA-1 rating for Port Neches; Sarnia, Canada; Los Angeles, Port Neches and Houston. All but the Houston unit, which is scheduled for 60,000 tons, have 30,000-ton capacity.

Four plants have been completed under an AA-2X rating. These are two 30,000-ton units at Akron, Ohio; a 45,000-ton unit at Louisville, and a 30,000-ton unit at Naugatuck, Conn. Under this

same rating, three units remain to be completed—two with 30,000-ton capacity at Los Angeles and Port Neches, and a 60,000-ton plant at Lake Charles, La.

Styrene plants are less numerous. By May 17, only three were in production. A marked improvement has occurred during the summer, though, with the following units now operating:

Texas City, Tex., 20,000 tons; Midland, Mich., 12,000 tons; Institute, 25,000 tons; Los Angeles, 12,500 tons; Texas City, 17,000 tons; Pittsburgh, 37,500 tons; Sarnia, 10,000 tons and Los Angeles, 12,500 tons. A plant with 50,000-ton capacity, at Velasco, Tex., began operating in late July.

For the manufacture of butadiene, 25 plants have been scheduled. Of these six were in operation by May and several more ready during early summer. The six original units and their capacities are: Baton Rouge, 6,600 tons; Charleston, W. Va., 5,000 tons; Institute, 80,000 tons; Baton Rouge, 6,800 tons; Baton Rouge, 3,100 tons. There are 18 active government projects.

***In these towers, through use of heat and pressure, refinery gases once used to heat plant furnaces now are separated to provide raw materials for synthetic rubber, 100 octane gasoline and toluene which goes into TNT.***

Now completed are: Baton Rouge, 15,000 tons; Los Angeles, 30,000 tons; Pittsburgh, 20,000 tons; Louisville, 30,000 tons.

Uncompleted butadiene plants are: Borger, Tex., 45,000 tons; Houston, 12,800 tons; Baytown, 30,000 tons; Pittsburgh, 60,000 tons; Louisville, 40,000 tons; Ingleside, Tex., 7,000 tons; El Segundo, Calif., 15,000 tons; Port Neches, 50,000 tons; Sarnia, 30,000 tons; Houston, 50,000 tons; Eldorado, Ark., 6,500 tons; Los Angeles, 12,000 tons; Port Neches, 50,000 tons; Lake Charles, 55,000 tons; Corpus Christi, Tex., 5,500 tons; Philadelphia, 10,000 tons and Toledo, Ohio, 15,000 tons.

In addition to these government financed butadiene plants, there are a number of small privately-owned units, with a total annual capacity of about 20,000 tons. In the government owned group, named above, seven represent refinery conversions.

If the present rate of stepped-up production is maintained, and if schedule dates can be met, prior fears that the American war effort would bog down for want of rubber may be forgotten. Hundreds of experiments have been conducted by petroleum engineers, chemists and rubber experts to "cut corners" in production and the results may be termed extremely satisfactory. As in so many other war industries, final production seems to be well on the way to exceeding planned capacity.

While many complex ingredients go into the making of synthetic rubber, and many competing processes are striving for ascendency in quick, plentiful, cheap and superior rubber production, the real mainstay of the rubber program is butadiene.

This precious base stock, retrieved either from petroleum or alcohol, is essential in the production of synthetic rubber.

Butadiene from alcohol represents about one-third of the government's program. The giant installations now being completed by the oil refineries will contribute the rest. If the synthetic rubber industry remains after the war, the big rubber companies—which are displaying more and more interest in developing a home source for the materials that will go into tires and rubber goods—will be largely dependent on feed-stocks from petroleum, it is predicted.

Three general methods of producing butadiene from petroleum are in use today. Briefly, these are:

1. Production of butadiene from butylene.
2. Production of butadiene from normal butane.
3. Production by severe cracking of intermediate oils (napthas or heavier distillates) at high temperatures and low pressures, in tubular equipment or in regenerative "stoves", or ovens.

The butylene dehydrogenation process (known as the "Jersey process" because of its development by Standard Oil Co. (N. J.) will take care of approximately 65 per cent of the government's butadiene-from-petroleum program.

Raw materials for the Jersey process are derived from refinery cracking operations—generally catalytic—for the production of butylenes. These operations yield a stream containing the desired normal butylenes, along with isobutylenes, isobutane, normal butane and small amounts of lighter and heavier materials.

The first step in the process concentrates normal butylenes by a combination of extractive distillation to reject paraffins and sulphuric acid extraction to remove isobutylene. In the dehydrogenation step, superheated butylenes are admixed with superheated steam in proper proportions in the top of large cylindrical reactors and pass through a catalyst.

Immediately below the catalyst space in the reactors, there is a "quench arrangement" by which the effluent vapors are cooled rapidly to temperatures below those at which the butadiene would be destroyed by further reaction. The vapors are further cooled and then pass on through conventional absorption and recovery equipment to turn out a stream containing the butadiene and unreacted butylenes.

The last step, butadiene purification, is accomplished by a combination of straight fractionation and extractive distillation, or by solvent extraction.

Butadiene production from normal butanes is done catalytically, by the Houdry or Phillips processes. Normal butane is converted to butylene and thence to butadiene, unconverted materials being recycled in the process.

The third general process involves thermal cracking at high temperatures and low pressures to favor butadiene formation.

Equipment used in butadiene production is essentially similar to that employed in other refining operations, including fractioning columns and related equipment; large reactors; heaters and purification equipment. In the case of thermal operations such as the one conducted by the Southern California Gas Co., regenerative stoves, constructed of brick, also are used.

The close similarity between synthetic rubber and the natural product has proved invaluable to the large-scale operations now in progress.

After the butadiene has been formed by the various processes sketched above, a synthetic latex is formed by mixing and emulsifying the chemicals. During the washing and heating, milling, compressing and other processes that follow, the

(*Continued on Page* 52)

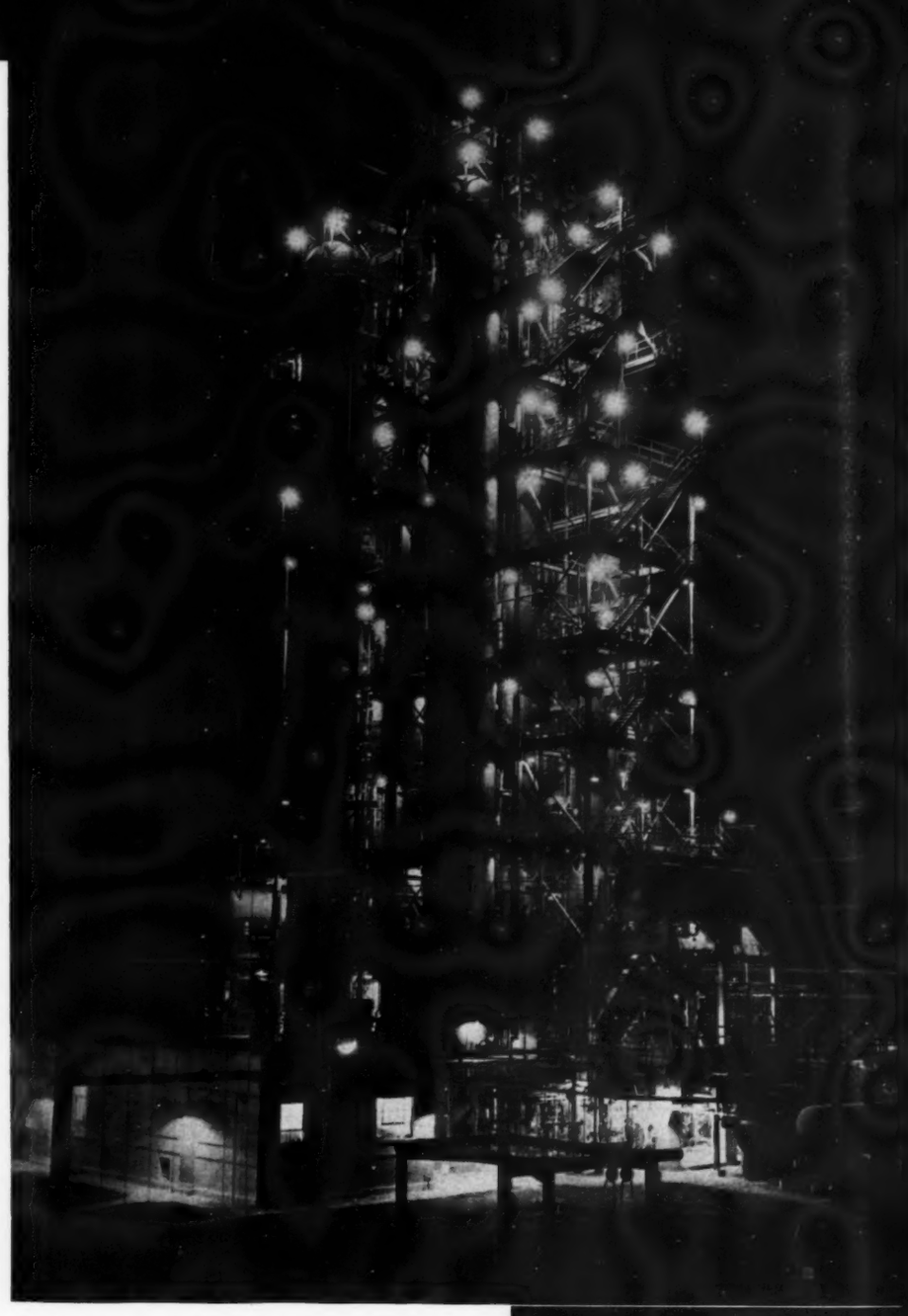
# BIG TEXAS PLANT SUPPLIES STYRENE FOR BUNA S

**Built in Less Than a Year Monsanto Chemical's Installation on Galveston Bay Is Shipping Essential Raw Material to Six Manufacturing Units for Conversion to Synthetic Rubber.**

IN the making of Buna S type of synthetic rubber which is to form the major part of the plant output in the program now being pushed rapidly toward completion the principal raw materials employed are butadiene and styrene. The proportions in which they are combined are approximately 75 per cent butadiene and 25 per cent styrene. Under the plans adopted the principal source of the butadiene is in various petroleum refining processes, but a substantial fraction of it is obtained from grain alcohol. The styrene is produced from ethylene and benzol. The former is derived by applying a cracking process to propane. The latter comes from coke oven gases.

Thus there are three types of plants participating in the production of Buna S rubber: the butadiene and styrene plants supplying the raw materials and the copolymer plants in which the fabrication of the finished product takes place. The making of butadiene from petroleum is carried on mainly in units which form part of large refining plants since its production goes hand in hand with that of aviation gasoline and other products of refining. Styrene employs some of the same processes and equipment as petroleum refining and its production is in the hands of companies with past experience in petroleum chemistry. The actual manufacture of butadiene and styrene into tires and other forms of rubber goods is carried on by companies affiliated with and directed by rubber manufacturing companies. The procedure followed is very much the same as is used in the handling of natural crude rubber and the technical knowledge possessed by these companies makes them best fitted for this branch of this work.

The first large scale styrene plant to go into operation—that of Monsanto Chemical Company at Texas City, Texas, began shipping its product on March 10, 1943. This was just seven days less than a year from the time when contruction had begun. The first shipment went to the Goodyear polymerization plant at Akron, Ohio, where it joined with butadiene produced from alcohol at the Institute, West Virginia, plant of the Carbide and Carbon Chemical Corporation, to emerge as the government's first synthetic jeep tire which, in honor of the event, was delivered to Rubber Director Jeffers in Washington. At the present time six rubber making plants are receiving a large part of their styrene requirements from Texas City.



*Reaching into the sky 20 stories above ground is this distillation tower of the Monsanto styrene producing plant at Texas City, Texas. The $17,000,000 plant went into production seven days less than a year from the time basic construction was started.*

Though it was not until the current year that Monsanto became a producer of styrene for synthetic rubber this company had been interested in styrene since 1938 when its plastics division at Springfield, Mass., introduced a plastic molding material based on styrene. The plastic first marketed found an expanding field and has since become one of the company's key products, being extensively used in military and essential civilian applications.

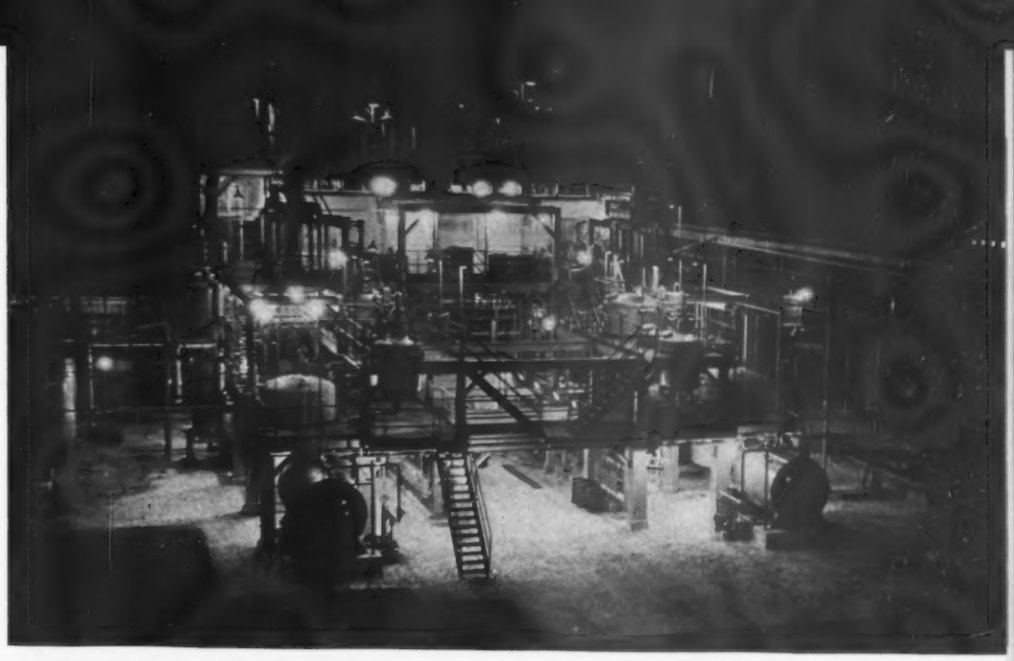
In 1939, this interest led the company to inaugurate an extensive research program looking

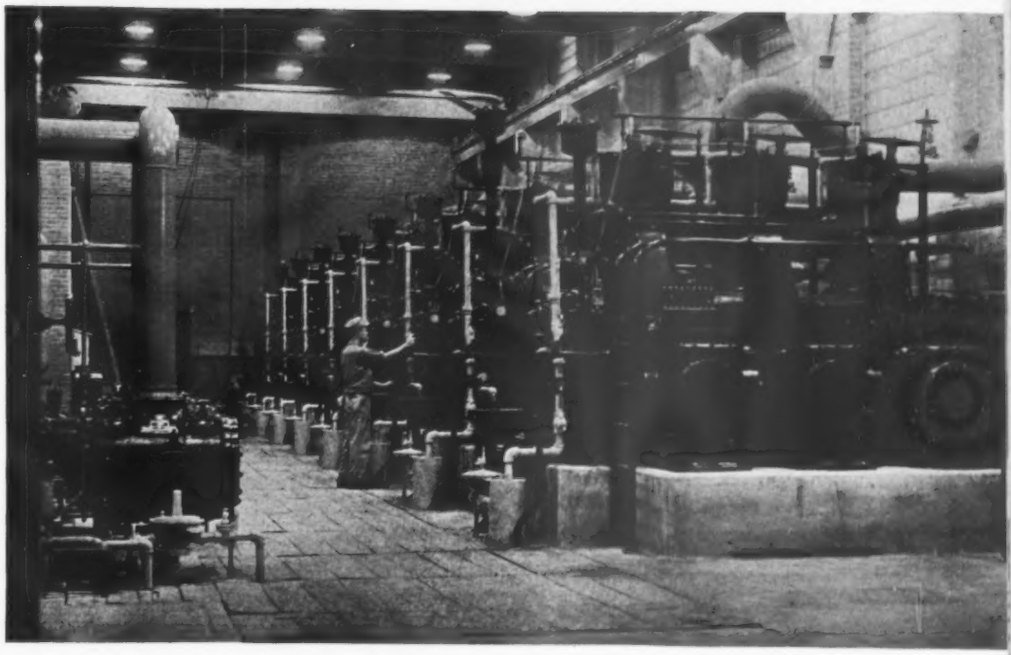
toward the development of improved processes for the manufacture of styrene and its related compounds. Work began at Monsanto's Central Research Laboratories at Dayton, Ohio, where a group of chemists and chemical engineers were assigned to the problem. In undertaking this research, the company had behind it the experience of thirty years in the manufacture of chemicals classed as aromatic hydrocarbons, of which styrene is a type. The work at Dayton was supplemented by a similar research carried out by divisional research laboratories of the company.

By the summer of 1941, the research program had progressed to the point where a process for the large scale manufacture of styrene from petroleum and coke oven by-products had been worked out. Following usual practice, construction of a pilot plant was then begun at Dayton.

Along with these developments in 1941, the international situation focused the attention of the nation on synthetic rubber. When Monsanto began its research, the largest uses of styrene were in plastics, even though its usefulness in Buna S synthetic rubber was known. With the approach of war the country's dependence on distant sources for natural rubber began to disturb military authorities and the Rubber Reserve Company, a subsidiary of Reconstruction Finance Corporation, was set up by the government. The

*At Texas City, Texas, where styrene, one of the raw materials used in the making of Buna-S synthetic rubber is produced, this maze of pipes form the processing service lines. In the background is a dehydrogenation plant.*





*Top: In this unit of the styrene plant the alkylation of ethyl benzene processing begins. Intricate engineering has brought about plants such as the one pictured without roofs or side walls. They are often referred to by workmen as "Battleships".*

*Bottom: The water pumping station at the Texas City government-owned styrene plant pumps 35,000 gallons per minute—the equivalent of the requirements of a city of 500,000 population.*

function of this company was to anticipate a possible shortage of rubber by amassing a stockpile of the raw natural product and to sponsor a program for the production of rubber from raw materials available in this country.

In the summer of 1941, the first contact between Monsanto and the Rubber Reserve Company was made. Monsanto had ready its process for making styrene and when the decision was made to concentrate the synthetic program on Buna S, requiring styrene, negotiations were opened. Before Pearl Harbor an agreement was reached under which Monsanto was to design, construct, and operate a small styrene plant.

In the latter part of 1941, the agreement was completed and a site at Texas City, Texas, was chosen. The actual property acquired was occupied by buildings of the Texas City sugar refinery which had been abandoned some years before. The location was near the sources of raw materials; some of the facilities on the property could be rehabilitated for use and the waterfront location supplied unlimited quantities of cooling water, necessary in the process.

On February 5, 1942, Monsanto set up the Texas Division to handle both the Texas City plant and another government plant at Karnack, Texas, to be operated for the Army Ordnance Department in making explosives. Osborne Bezanson was appointed general manager of the new division.

Actual work at the Texas City plant site got under way in February 1942, with dredging begun to raise the ground level. Meanwhile groups of design engineers at St. Louis, Dayton, and Texas City proceeded on plant design. The original plans for the plant have been drastically revised several times. Starting off before Pearl Harbor as a relatively small operation, the goal has been progressively lifted until contemplated capacity now is sixteen times that originally laid down. The last revision was made in the summer of 1942.

The first alkylation unit went into trial operation on January 2, 1942. The first tank car of styrene was shipped from the plant on March 10, 1943 as already related. In the preceding twelve months however a lot of gruelling work had gone into the construction and equipment of the plant. At the start of the job the project was known to be a large one but no one in the early days could anticipate the development that was to take place even after construction began. From January until August, 1942, the size of the plant was increased or altered steadily, which meant constantly changing burdens to an overworked engineering organization.

One of the difficulties constantly facing the organization was the closeness with which construction crowded design because of the urgency of producing styrene. This was no plant which could go from laboratory design stage to working pilot plant stage and then be stepped up in geometric proportions as the engineers improved their designs and ironed out the "bugs".

Large scale production had to be the first step after laboratory. At many times the engineers began to believe that the scoffers might be right, that they were "crazy chemical engineers," but they would refigure their plans, go over them time and time again and come up with renewed confidence that the plant would work when completed.

The vastness of the project can be realized through a few statistics and factual statements:

The Texas City plant will make sufficient styrene, which when combined with three times as much butadiene from other sources, could be used to manufacture rubber that normally would be produced from 60 million rubber trees covering 600,000 acres of ground.

Before the piling was driven, part of the plant site covering 13½ acres had to be filled in with sand pumped in from the bed of Galveston Bay.

The following metals were required: 13,250 tons of steel and iron, 290 tons of copper and alloys, 260 tons of alloy steel, and 16 tons of nickel alloys.

More than 2,600 construction tradesmen took an essential part in the building.

The plant's major unit, the distillation tower, is equal in height to a 20-story office building.

The water pumping unit is capable of pumping 35,000 gallons of water a minute—sufficient water to supply a city of 500,000 population.

Twenty per cent of the plant is underground.

The plant is so lighted at night that the crew of an airplane going overhead cannot see the lights, although an observer on the ground is impressed with the brilliance of the spectacle.

The plant can be blacked out completely in less than 60 seconds and still remain in complete operation, in the event of an attack by enemy aircraft or submarines.

The production capacity of the Texas City plant even before working drawings were started was set at 3,000 tons per year. In rapid succession the design was changed to increase capacity to 6,400 tons, then to 10,000 tons, and in January, 1942, revised upward to 20,000 tons; in April to 40,000 tons, and in September, 1942, to 50,000 tons.

Thus, when completed and in full operation in the fall of 1943, the plant will supply a substantial part of the styrene produced in the United States for the manufacture of Buna S synthetic rubber.

Styrene is described by chemists as "an aromatic hydrocarbon compound having a double bond". This double bond is the key to its usefulness in both plastics and in synthetic rubber. The double bond on each molecule of styrene enables individual molecules of the compound to be linked together into long chains. This polymerization process radically changes the appearance and physical and chemical properties of the material. When styrene alone is polymerized, it is changed from a clear-white liquid to a hard, dense glass-like substance. When styrene and butadiene are polymerized together, the product is a rubber-like material known as Buna S.

Production of styrene at the plant is based on two raw materials—propane, a petroleum fraction, and benzene, a by-product of coke ovens. In the first step, propane is cracked to supply ethylene gas. This cracking is somewhat similar to methods used in the petroleum refining industry. By alkylation the ethylene gas and benzene are then combined in the second step to form ethylbenzene.

Styrene differs from ethylbenzene by having two less atoms of hydrogen. Ethylbenzene is converted to styrene by removal of the extra hydrogen in a dehydrogenation process.

In designing and in operating the plant, Monsanto has been able to draw not only on its own technical resources but on the background and research of every other company in the field. Through the Rubber Reserve Company, an industry technical committee provides for the free interchange of information. Through this system several companies, normally highly competitive in peacetime, work together for the war effort. As a result, the design of the Texas City plant, although substantially a Monsanto project, uses some processes and methods developed by other companies.

***William M. Jeffers, Rubber Director (second from left), and Colonel Bradley Dewey, Deputy Rubber Director (right) atop the 212 foot distillation tower at the Texas City styrene plant, discuss the tower operation with Supervisor Merril Tyson (second from right) and Operator James Russell Dodds (left).***

# MAKING SYNTHETIC RUBBER AT INSTITUTE

**Group of Plants Produce the Raw Materials, Butadiene and Styrene, and Combine These in Copolymer Units Which Will Turn Out 90,000 Tons of Buna S Yearly**

IN JULY of this year the synthetic rubber plant at Institute, West Virginia, came into full operation with the completion of the third 30,000-ton unit for the production of Buna S rubber. The first unit had attained production earlier in the year and the second one was completed about the first of June.

The Institute plant was built for the account of the United States government and is operated by two companies: the Carbide and Chemicals Corporation, which produces the raw materials (butadiene and styrene), and the United States Rubber Company, which takes these raw materials and compounds them into synthetic rubber of a kind that most closely resembles natural rubber. The whole installation is rated to produce 90,000 long tons of the synthetic product (Buna S). The rubber division of the installation as a whole is really three independent factories, each of which can operate separately, so that if anything happens to one the other two may continue to function.

Some statistical details may help to put the project in perspective. The factory area covers 77 acres, and was built at a cost to the government of $56,000,000. The 90,000 tons of synthetic rubber which this factory is expected to produce in one year is about one seventh of the normal consumption of rubber in the United States. This amount of synthetic rubber would be enough to make 63,000 pasenger car tires a day (if it were all used for that purpose), or 16,000,000 passenger car tires in a year. It has been calculated that to produce an equivalent amount of natural rubber on even the best East Indian plantations would require 270,000 acres of land containing 24,000,000 rubber trees. To get such a plantation started would require an investment of $80,000,000 and five years would pass before any rubber could be tapped, and after that a labor force of at least 90,000 native workers would be required. In contrast, the Institute rubber plant at full production will be operated by a staff of about 1,250 persons, which includes those engaged in production of the raw materials and in compounding. The plant consumes 197,000 gallons of industrial alcohol per day for the production of butadiene. If this alcohol were made by fermenting corn, the American farmers would have to plant 720,000 acres of corn a year (an area nearly three times greater than the natural rubber plantation mentioned above), and more than 15,000 farmers would be needed to produce this corn. However there are cheaper ways of obtaining alcohol than by corn farming; it can be made from petroleum, or from coal and limestone.

The manufacture of rubber at Institute begins with the production of butadiene. This butadiene plant actually consists of four separate though identical units, each of which is rated to produce 20,000 short tons of butadiene a year, or a total of 80,000 tons for the four units. Alcohol from storage tanks having a total capacity of 7,500,000 tons is fed to converters where, through the action of heat and certain special catalysts, it is converted into butadiene. The butadiene, which must be 98.5 per cent pure, is a gas even at temperatures below the freezing point of water. To keep it in the liquid form it is necessary to subject it to heavy pressure, and in this form it is stored in pressure tanks and delivered to the rubber factory through pipes.

The other raw material of Buna S is styrene, which is a liquid. It is made from benzene, a well-known hydrocarbon that is found in coal tar and may be (and is) made from petroleum, and from pethylene, another gas. The ethylene is made from petroleum at a plant owned by Carbide and Chemicals Corporation at Charleston, some five miles distant. This same ethylene can be used to produce alcohol more cheaply than it can be made from corn so that a synthetic rubber industry can be maintained without any large use of agricultural materials. A catalytic union of benzene and ethylene produces ethyl benzene, which is further treated to produce styrene.

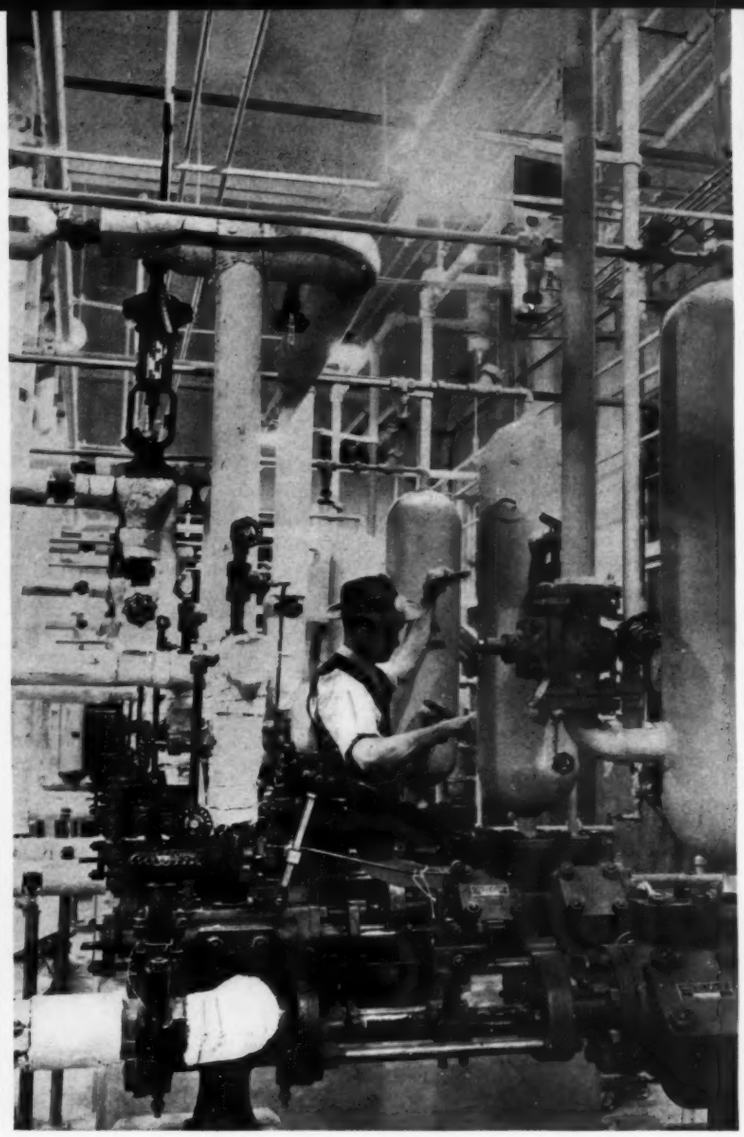
The prepared butadiene and styrene are now brought together in an assemblage of apparatus known as the "copolymer plant". The copolymerizing operation depends on the fact that butadiene and styrene are unsaturated hydrocarbons: that is, their molecules have certain vacant "bonds" by which they have the ability to unite with other substances. When butadiene and styrene are mixed together the molecules of the one substance begin to hook up with the molecules of the other substance and the result is a tough, rubbery substance. The hooking-up process cannot be allowed to proceed too far, otherwise the product will become less usable as rubber.

To induce the butadiene and the styrene to copolymerize properly some rather elaborate arrangements are necessary. Merely mixing the two main ingredients will not suffice. They must be brought together in the presence of a catalyst that will set off the molecular hooking-up process and keep it going. In order that the two raw materials and the catalyst may properly react they must be brought into intimate contact with one another. This is effected by whipping them up in a solution of soap, whereby everything, including some special chemicals, is reduced to the consistency of a smooth cream. All these materials have to be present in accurately measured amounts, but this task of proportioning has been reduced to a point where the operator, by merely pushing a lever, causes all of them to assemble in the right proportions for a batch.

From this point on the reader may follow the operation with the aid of the flow sheet on page 30. This flow sheet shows, first, the tanks in which the butadiene and the styrene are stored. From these storage tanks pipes converge on the vessel known as the polymerizer. This is a vessel which is surrounded by a water-jacket, through which cold water circulates to keep down the temperature; this cooling is vitally necessary for the proper control of the reaction. At the top of the polymerizer is a pipe for the admission of the soap solution, water, the catalyst, etc., the whipping-up stirrer is set in motion, and the polymerizing process gets under way. The small globules of oily substances become thicker, more viscous and rubber like; but as stated before, the polymerizing process must not be allowed to proceed too far, else the product will thicken to a point where it loses much of its desirable rubber-like properties. For this reason the progress of the reaction is carefully watched, and at the proper point the contents of the polymerizing vessel are dumped into the "blow down tank", where a reagent called the "short stopper" is injected into the batch to stop any further polymerization. The mass in the blow down tanks, which now contains the crude Buna S along with some unreacted butadiene and styrene, is admitted into the "flash tanks" where the excess butadiene, owing to its gaseous nature, flashes off and returns to the butadiene storage tanks to again take part in the cycle. The excess styrene, being a high-boiling liquid, is distilled off with steam in the stripping column and also returns to the process. After that, the crude reaction product enters the latex-blending tank where it receives a dose of antioxidant to protect it from corruption by atmospheric oxygen. At this stage the product is still in the form of a latex, or a whipped-up cream consisting of very small particles of rubber. To de-cream this mixture the mass is stirred up in the brine tank with a strong solution of salt, which causes the small particles of rubber to coagulate in the form of larger flocs.

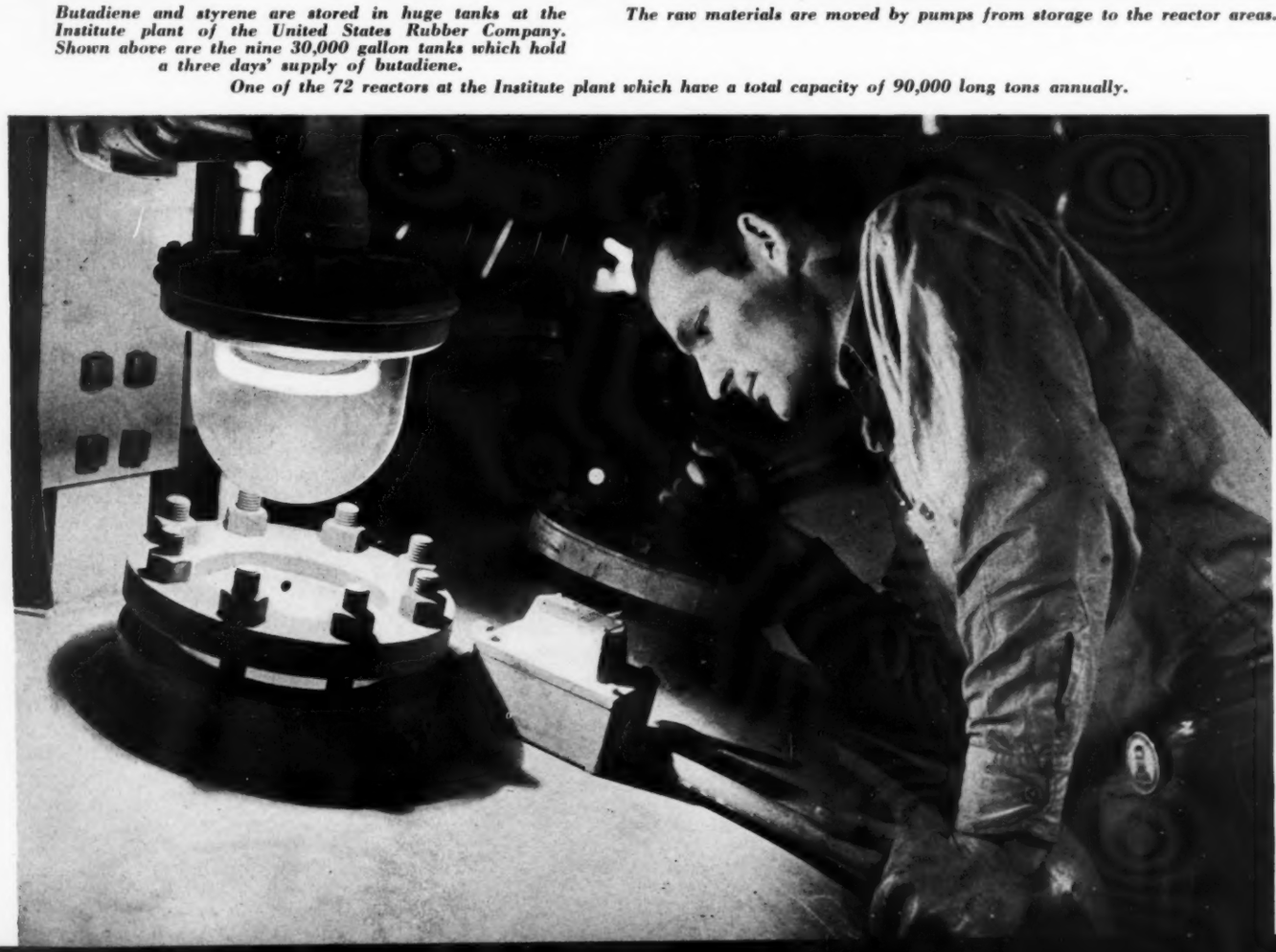
This process is accelerated and finished in the next tank by an acid treatment. All this while the product has been accompanied by the soap that was added to produce the cream. This soap is now converted into liquifiable fatty acids, leaving the rubber as the only undissolved solid in the mixture. The solid rubber is then easily collected on a vacuum filter, where it can be washed. The caked mass from the filter is then broken up by a disintegrator, the pieces are dried and pass over an automatic weighing machine, after which they are baled for shipment to the tire factory. The whole process is under control, from start to finish, by a staff of chemists and analysts, who daily examine an average of 1,800 samples.

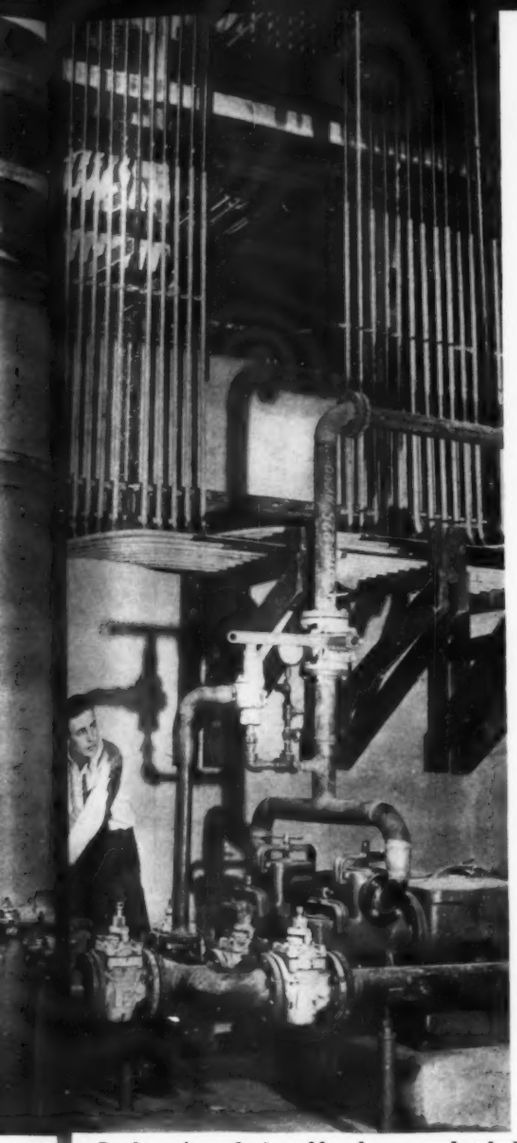
*Butadiene and styrene are stored in huge tanks at the Institute plant of the United States Rubber Company. Shown above are the nine 30,000 gallon tanks which hold a three days' supply of butadiene.*



*The raw materials are moved by pumps from storage to the reactor areas.*

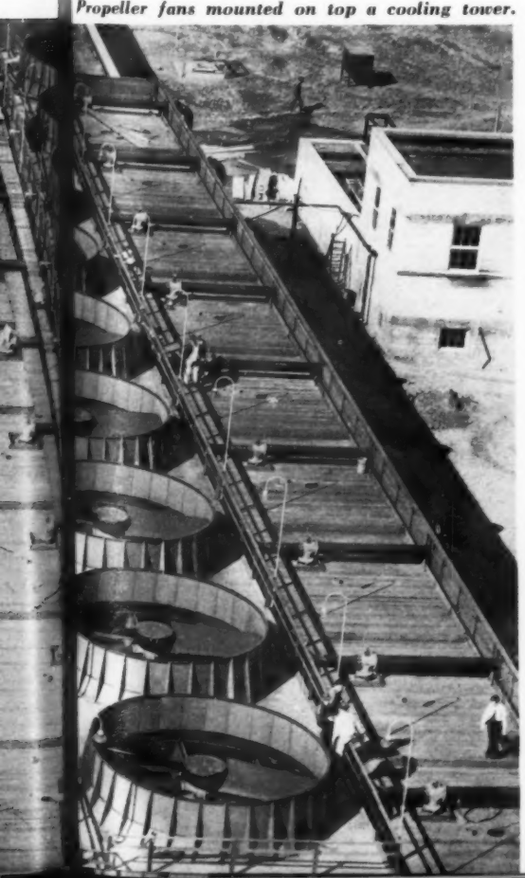
*One of the 72 reactors at the Institute plant which have a total capacity of 90,000 long tons annually.*





*Batches of synthetic rubber latex are batched and blended in twelve concrete storage tanks, and then pumped to other tanks where the rubber content is coagulated and separated in the form of flocs or crumbs.*

*Propeller fans mounted on top a cooling tower.*



*Right: Operator carries a bomb of styrene in the laboratory where a staff of 100 chemists and analysts control all phases of both raw materials and finished product.*

*Center: After the synthetic rubber has been washed and excess water has been removed, it is conveyed in the form of a blanket of machines which reduce it to smaller particles before drying.*

*Bottom: Buna S synthetic rubber is pressed into a loaf 18 by 28 by 6 inches, weighing 75 pounds. George A. Graham, factory manager of the Institute Plant, is shown inspecting a loaf as it comes from the hydraulic press.*

# RELATION OF PETROLEUM TO CHANGING WAR SITUATION

**European Axis Powers Faced by Inadequate Supplies of Oil and Inability to Enlarge Them—Waning Power of Luftwaffe Reflects Fatal Defect that Insures Their Defeat.**

Two developments within the past few months have materially altered the petroleum situation in its relation to the war, more particularly as concerns the European theatre of operations. The first of these was the expulsion of the Axis from North Africa; the second is the reduction of the submarine menace to Allied shipping in the Atlantic. The delivery of the entire southern shore of the Mediterranean from the hands of the Germans and Italians is an achievement, the importance of which may best be judged by recalling that less than a twelvemonth earlier the army of Gen. Rommel was almost at the gates of Alexandria and was threatening the Allied hold on the Egyptian oil fields, Suez and the entire Near East.

Removal of that menace, with the reasonable certainty that it will not recur, followed by the clearing of the Mediterranean to the passage of Allied shipping, greatly eased the transportation burden of the United Nations. Since oil, as frequently has been pointed out, imposes the major tonnage requirement in the movement of military supplies relief from the necessity of moving tanker cargoes and fueling naval and merchant ships on the long voyage around Cape of Good Hope has been equal in its practical effect to a 25 percent addition to cargo capacity to this particular area.

While the winning of the African campaign added nothing to the actual amount of petroleum products available to Allied forces, it meant that much larger quantities of oil, and of course other supplies, could be moved to the battle fronts and supply depots in the same time by an equal number of ships. It meant, too, that if necessary oil from the Near East could be transported to any point in the Mediterranean, or beyond if need be, to supplement supplies from the other side of the Atlantic.

Diminution of tonnage losses through U-boat attacks in the Atlantic and consequent freer movement of cargo carriers in that area, although strikingly in evidence during the past three months, cannot safely be counted upon as a permanent Allied gain. Should it continue, however, it will make possible the freer movement of oil-carrying vessels and the more rapid dispatch of their cargoes. It also will permit a broadening of the sources of oil supply and less complete dependence upon deliveries to the Eastern Seaboard of the United States for the maintenance of Allied military operations in Europe.

This is an important consideration. With the advance against the continent of Europe involving the employment of a greatly increased number of ships, planes and other motorized equipment the quantities of petroleum products required to keep these forces in action are rising at a very rapid rate. The problem of meeting these expanding needs under the conditions heretofore prevailing has long been a matter of grave concern to the supply services of the United States Army. Even with the improved transportation facilities provided by the opening of new pipe lines it was realized by the authorities in charge that it would not be possible to rely indefinitely on overland transport from the Mid-Continent and Gulf Coast to the Atlantic Seaboard to meet overseas requirements in addition to the minimum requirements of industry in the eastern states.

A more serious aspect of the situation was the conclusion reached by the military authorities that reliance upon the United States to meet ever-increasing war requirements, plus its own domestic necessities and the lend-lease commitments it had undertaken, would lead to a shortage of crude production within the next year or two unless this were to be avoided at the expense of serious injury to existing fields. Warnings to this effect had been given repeatedly by prominent geologists and experienced oil producers and had been reiterated by members of the Petroleum Administration for War. The condition was aggravated by the persistent refusal of the Office of Price Administration to permit a price for crude that would encourage the search for new fields.

Army and Navy authorities, who could not afford even to contemplate a lack of petroleum products adequate for the fullest imaginable demands of all-out war, proceeded to readjust their plans with a view to broadening the sources of supply. Their position was frankly explained by Lieut. General Somervell, commander of the Army Service Forces before a Congressional committee late in June. Pointing out that military requirements, exclusive of aviation gasoline, were above a million barrels daily and that a shortage of crude oil production to meet all requirements was a distinct possibility within the near future, he revealed some of the steps proposed to guard against any such eventuality hampering the prosecution of the war. One of these, he said, was the utilization of more oil from fields around the Persian Gulf. Another was the drawing of increased supplies from South America, particularly Venezuela and Colombia, and he referred to the desirability of enlarging refining facilities in both these areas.

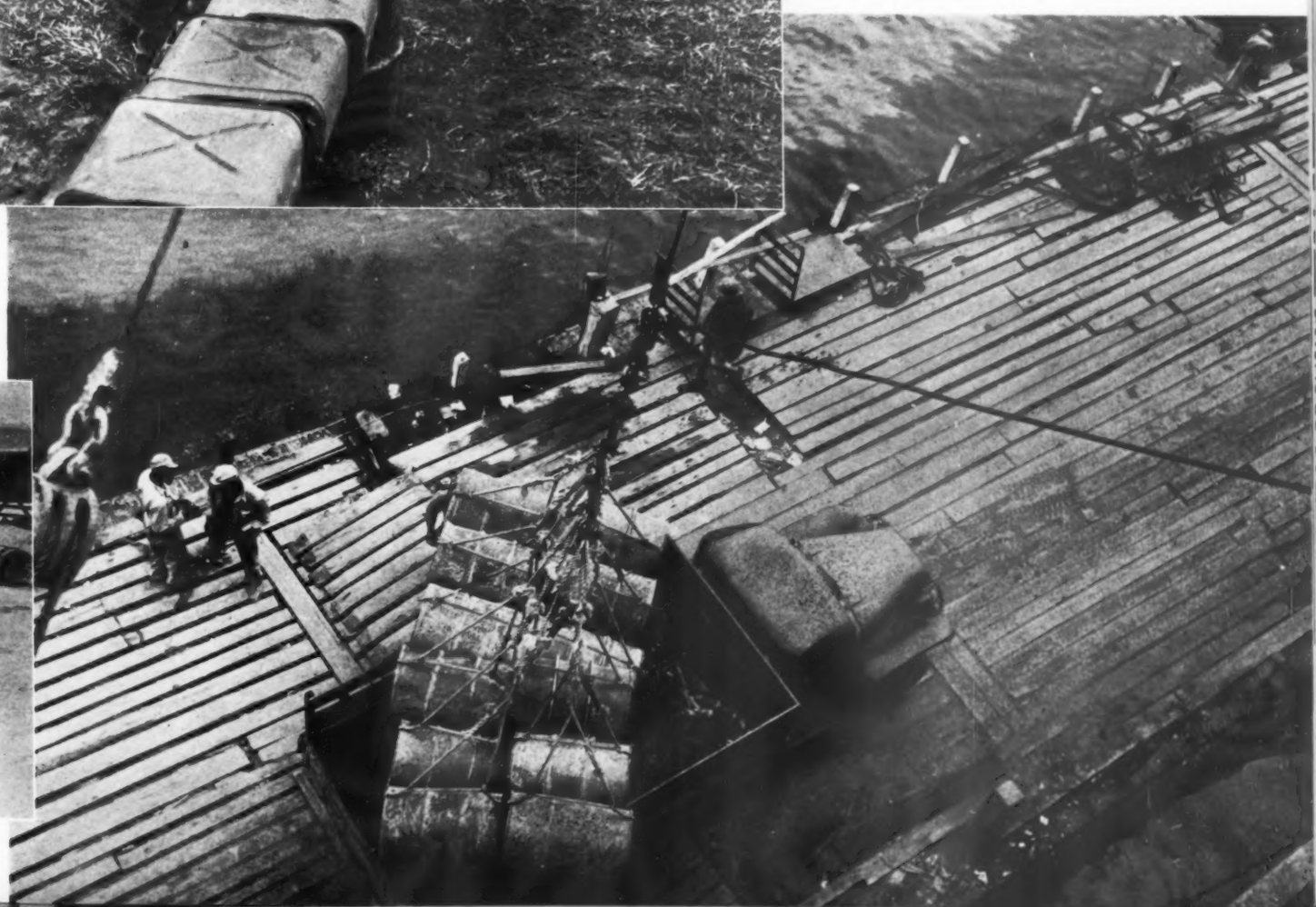
***A fuel dump abandoned by the Germans during their hurried retreat from the station of Kantemirovka in the Middle Don area.***

Production in Venezuela and Colombia has been reduced to less than half their pre-war volume by lack of transportation facilities. To increase the supply from those countries by 300,000 or more barrels daily is primarily a matter of providing tankers to move the oil. Capacity for refining this crude exists in the Netherlands West Indies. Adding this to the 200,000 barrels which he estimated as the additional quantity obtainable from the Near East would provide 500,000 barrels, sufficient to take care of a very considerable expansion in the scope of military operations outside of aviation fuel which it is apparently assumed will continue to be supplied principally by the United States since this country has the materials and a steadily growing number of plants equipped for the production of this type of fuel.

It is probable that Gen. Somervell would have been more reticent regarding projected plans for supplementing the oil supplies heretofore relied upon with additional amounts from other sources except for the two developments referred to at the beginning of this article—the freeing of the Mediterranean for Allied shipping and the lessened toll exacted by U-boats. It is known however that the military authorities for a long time past have taken a global view of petroleum's part in a global war. The Army has been responsible for exploratory drilling for oil in areas ad-

***Left:** Somewhere in England American soldiers are shown checking cans of gas in a petrol dump as they come in on a conveyor belt.*

***Below:** Drums of gasoline being unloaded from a Liberty ship at dock in New Guinea. Photos courtesy Signal Corps.*



***Soldiers operating portable gas driven pumps used to pump gas to four filling units in Australia. Photo courtesy Signal Corps.***

jacent to some of its important bases in the Pacific. While no official information has been released there is every reason to assume that careful preparations have been made both in equipment and personnel to utilize the oil resources of any oil producing areas that may be occupied in the course of the Allied advance on various fronts. This would be merely to follow the plan that the Nazis advertised that they were preparing to put into effect in their invasion of the Caucasus and that undoubtedly would have been put into operation if they had succeeded in getting possession of the oil fields. The Army and Navy know the military indispensability of oil and their intention is to get it and use it wherever they can, the closer to the seat of action the better.

Without speculating upon possibilities that may still be somewhate remote, such as the discovery of new fields in distant areas or the recapture of oil territories held by the enemy, it is clear that the situation of the United Nations in relation to its petroleum supplies has been substantially improved by the conquest of the Mediterranean and the reduction of the submarine hazard. On the one hand these developments permit more ready recourse to additional sources of supply and on the other they make possible a big increase in deliveries through a shortening of supply lines and the freer movement of shipping. Coming at a time when their petroleum requirements are being greatly expanded these gains will be of utmost importance.

Turning to the other side of the picture it is pertinent to ask how the latest devolpments in the war have affected the European members of the Axis in regard to their petroleum supplies. Military commentators have pointed out that in going to the defensive Germany and Italy have the advantage of shortened lines of communication. They are fighting from the inner run of a wheel while their opponents must attack around its circumference. There are obvious advantages in this position but there are also certain difficulties which under the conditions faced by the Axis powers ultimately will lead to their defeat. While they are operating within a circle that circle is surrounded by the armed might of the United Nations at virtually every point. The Axis cannot know where the attack may fall and consequently must be prepared to meet it from any direction. This necessitates a dispersal of forces that weakens their striking or resisting power. One of the reasons for the less efficient performance of the Luftwaffe is that it must be scattered over a wide area and cannot be concentrated for a single devastating drive as was the case in the attack on Poland or the subsequent invasion of the Low Countries and France.

Possession of a highly efficient transportation system would offset in some measure the handicap of having to be prepared to meet attacks from several directions at once but transport has been almost from the beginning a weak spot in Germany's armor. Its weakness undoubtedly has been increased by persistent Allied air attacks upon railway centers and rail equipment. To move the oil and other supplies required by the invaders is, as has been said, a tremendous task but much of this movement is over water routes controlled by the United Nations. Germany and Italy must convey the fuel for their fighting machines hundreds of miles by railway lines choked by the movement of troops and of other supplies. Even though the supply of oil products were ample for all Axis needs the problem of delivery to the right places at the right time is one of prodigious difficulty.

Oil for Italy, for example, except for the limited supply moving across the Adriatic from Albania, has been coming from Rumania, a rail or rail and water trip of more than a thousand miles. A nearer source of supply is Hungary but that also involves overland transportation of several hun-

dred miles and most of Hungary's oil probably is being used by the Nazis to supply their eastern front. Railway lines in Italy moreover are particularly exposed to air attack, a point that Allied air forces have not overlooked in recent weeks.

Germany itself is somewhat better situated in the matter of its oil supplies, having its domestic production, natural and synthetic, to draw upon as well as the fields in Rumania, Hungary, Austria and Poland. But the Nazis require very large supplies for their armies in Russia which must be moved over ill-equipped railway lines for distances varying from several hundred to more than a thousand miles. To supply the land and air forces defending their western sea approaches necessitates equally long hauls for which trackage, tank cars and locomotives are all insufficient.

Predictions made at the beginning of the present conflict that in a prolonged struggle Germany and Italy would be handicapped by a shortage of oil are sometimes quoted by critics who ask tauntingly why this shortage has not made itself felt after four years. The fact is that no informed person ventured to forecast that the shortage would be quickly manifest, particularly so after the successful Nazi forays of 1939 and 1940 when they acquired substantial stocks in addition to those accumulated before the start of the war.

Nevertheless, there is accumulating evidence that the Axis now is feeling the pinch of insufficient aviation fuel and lubricants. The weak response of the German air arm to the widespread bombing attacks launched from Britain, the lack of vigorous air resistance in Tunisia and Sicily and the sparing use of bombers and fighter planes on the eastern front all are straws indicating that the Axis no longer can expend its air weapons with the same prodigality as during the early stages of the war. The restrictions upon its use of planes undoubtedly reflect in part a growing scarcity of aviation fuel. While actual production may not have diminished it is less by comparison with the greater needs imposed by the necessity of maintaining adequate air strength on many fronts. The inferior performance of Axis planes in combat likewise suggests a lack of thorough training for its pilots, again due to a deficiency in fuel for this purpose.

While exact statistics of natural oil production within the territory under Axis control are not available the possibilities in this direction are fairly well known. They include the output of fields in Rumania, Hungary, Albania, Poland, the Reich itself and former Austria. Of these the most important is Rumania with a possible outturn of 6,000,000 tons a year. Germany, with Austria, may add another 1,500,000; Hungary and Poland perhaps 1,000,000. Albania, before the war, produced about 200,000 tons. Italian claims that this production has been doubled are viewed by oil men acquainted with the country with a high degree of skepticism. The Pechelbron field in France and the small output of Czechoslovakia can hardly amount to more than 100,000 tons. Making a liberal allowance for production in all these areas it can hardly be more than 8,500,000 tons, less than 60,000,000 barrels. Certainly this is far below the quantity required to carry on a conflict of the kind now confronting the Axis.

It is impossible to speak with any degree of certainty regarding the quantities of synthetic petroleum products, or petroleum substitutes, being produced by Germany and Italy. When the war started Germany's output of these products was close to 2,000,000 tons yearly. Plans announced by the Nazis contemplated raising production to 4,000,000 tons by 1942. It is known that certain plants then projected or under way have been completed. It is possible that others have been added but it is doubtful if the goal set four years ago actually has been reached.

Because of nearness to coal and lignite and the convenience of water tranportation a large part

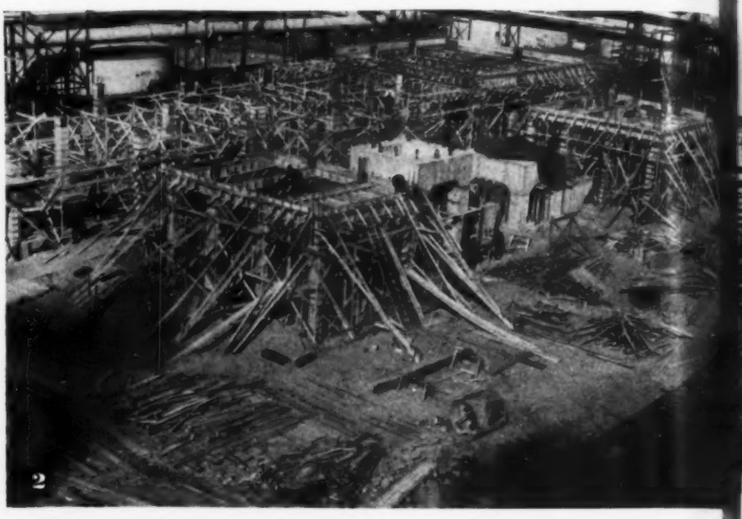
(*Continued on page* 56)

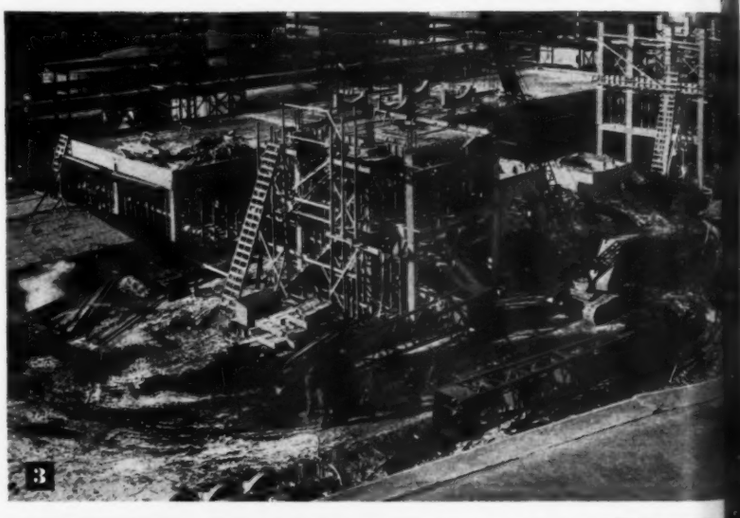
***The White Pass & Yukon Line is a twisting, narrow-gauge railroad, built four decades ago to tap the gold fields of the Klondike. It is now the artery which feeds the new Alaska International Highway from the sea.***

# GROWTH OF AN OIL INDUSTRY WAR PLANT

***Better than any mere word picture the camera tells the story of the rapid growth from sand lot to towering completion of the oil industry plants that have been springing up throughout the country during the past year. The accompanying illustrations depict the growth of one such typical unit. This is a crude naphtha fractionator erected by Standard Oil Company (Indiana) at one of its main refining centres. It is from scores of plants such as this that the flow of special products required for war use has been enabled to keep pace with the swiftly mounting demands of expanding military operations.***

PHOTOS COURTESY STANDARD OIL COMPANY (INDIANA)



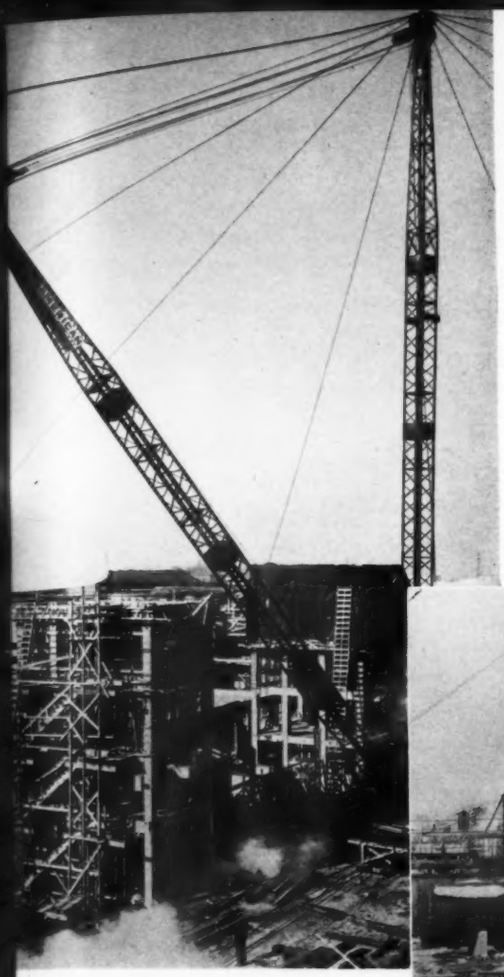

*1. October 5, 1942. Forms for reinforced concrete supports are placed in excavation.*

*2. October 27, 1942. The reinforced concrete supports begin to take definite form.*

*3. December 11, 1942. The substructure of the unit is growing rapidly now.*

*4. December 18, 1942. Concrete has reached third floor height.*

*5. January 14, 1943. Structure is up to four story height now and still climbing.*



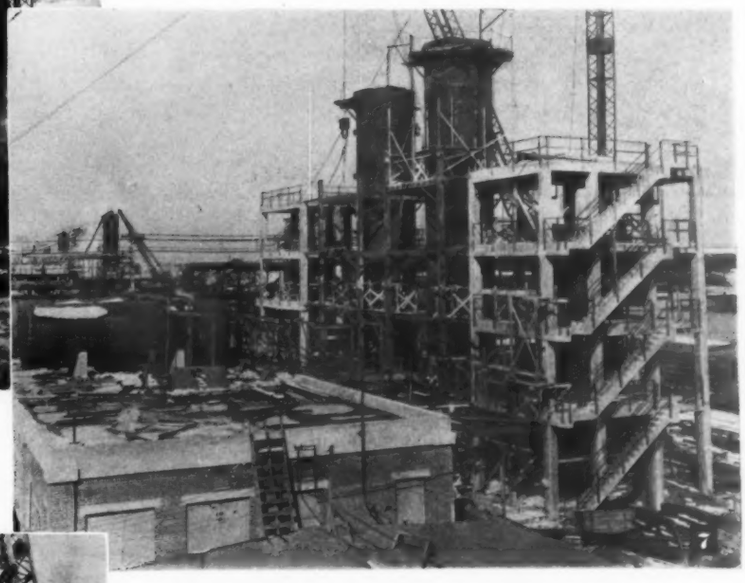
*6. February 1, 1943. At close range the giant crane used in the construction work seems to be forming a V for victory.*

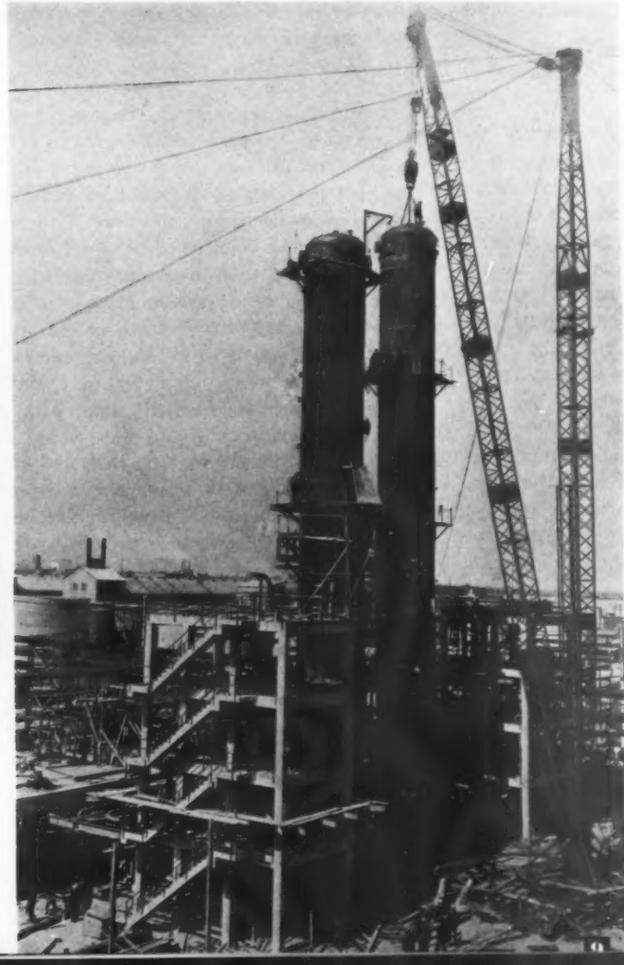
*7. March 8, 1943. The concrete is complete now and steel towers are rising in the center.*

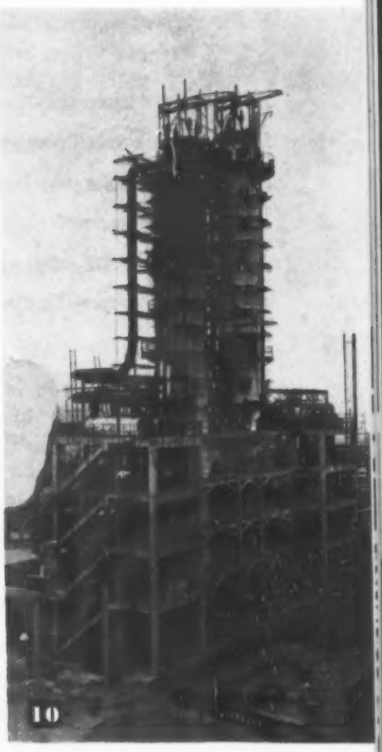
*8. March 22, 1943. Here is how the fractionating towers look on closer inspection.*

*9. April 3, 1943. The towers are complete but not yet equipped with supplying lines on superstructure.*

*10. June 12, 1943. The unit practically completed and near the day when its operation will begin.*







*Synthetic rubber has proved its superiority to natural in contact with oil, grease and most corrosive materials.*

# SYNTHETIC RUBBER SERVES MANY USES IN PETROLEUM INDUSTRY

**Ability to Impart Special Qualities in Process of Compounding Makes Synthetic Superior to Natural Product Where Resistance to Heat, Abrasion and Other Destructive Influence Is Called For**

WHEN the petroleum industry accepted the task of cooperating with the rubber companies in creating a replacement for the natural rubber lost in the South Pacific, the immediate objective was in the nature of an emergency. America needed its rubber. The situation was perhaps more desperate than some of us imagine and many, including experts in war strategy and leaders in government, held their breaths in anticipation of results. The results we now know.

A vastly different conclusion has come out of this enforced change, however. In addition to adequately replacing the services of natural rubber, the rapid development of a synthetic product has, in a very definite measure, created a "displacement" of the crude rubber formerly imported from Malaya and the East Indies. Synthetic rubber could rightly be classified as an entirely new product, with the desirable characteristics of natural rubber, plus many advantages that the common place rubber does not have. Getting into production of raw material, such as butadiene, in an amazingly short time is an accomplishment worthy of highest praise because the war needs called for quick action. This the petroleum and rubber industries did with only one thought in mind—the winning of the war.

**By John A. Tallant**
Manager Technical Data Service
Hycar Chemical Company

The petroleum industry has, in this pioneering for a strategic material, added greatly to its own facilities and efficiency by developing a product that answers many of its own production problems. Perhaps of minor importance is the value to the petroleum industry of crude oil consumption in the production of synthetic rubber. Out of the total volume of petroleum produced in the United States, less than one half of one percent would be required to supply us with our rubber requirement. However, there will be a continuing market for butadiene and other such raw materials after the war and these could well prove to be the foundation of a new petro-chemical branch of the oil industry, with considerable economic importance. The real significance of synthetic rubber to the petroleum industry lies in the new performance miracles arising from synthetic development in the able hands of our chemists and engineers. For example, the needs of war called for an aviation gasoline tank that would seal itself when punctured by machine gun fire. Synthetic rubber, made from a butadiene answers this need. This self-sealing tank has saved the lives of countless American aviators, otherwise forced to bail out over enemy territory because there was no gas for a safe return home.

Out of this development also have emerged many product applications that will directly benefit the petroleum industry from an operating standpoint. Bullet sealing tanks and hose demonstrate synthetic's high resistance to gasoline, a quality not present in ordinary rubber. The use of this same synthetic is therefore logical in the industry's production facilities, where its equipment is in almost constant contact with petroleum in one form or another.

In a series of tests made by the Hycar Chemical Company, it was demonstrated that butadiene synthetic rubbers are far superior to ordinary rubber in many important respects, a number of which have a direct bearing upon applications in the petroleum industry. Hycar synthetics are extremely resistant to all petroleum products, from crude to the lighter fractions, such as butane and propane and including the more complex by-products. The actual degree of swelling will of course, depend on the exact compound used and the conditions under which the exposure takes place. The compounding, however, can be controlled to achieve practically any desired result. For instance, if absolutely no change in volume on immersion in oil was desired, a compound could be designed to meet this condition. On the other hand, if a slight swelling is desired, as might well be the case for a specific sealing purpose, this could likewise be obtained with the right stock.

Under the severe service conditions encountered in the petroleum industry, Hycar synthetics retain their extreme oil resistant qualities even under temperatures of 250 degrees Fahrenheit, or higher where the exposure is intermittent and for short periods.

In the case of immersion in oil and many other solvents, Hycar not only resists swelling, but its tensile strength, abrasion resistance and other original qualities are well maintained. In the laboratory tests of natural and synthetic rubbers, both were subjected to the same abrasion tests. Hycar was 50 percent better than natural rubber in abrasion resistance, and this is even more pronounced where oil or grease might be present which means that Hycar will come into more and more applications where there is friction or wear—clutches, belts, shock absorption equipment and brake linings. The better performance of Hycar in tests under which natural rubber would break down was maintained even when the compound was exposed to oil, heat, aging and other adverse conditions.

To the petroleum industry, these facts are of particular significance, since the conditions under which parts and other equipment must function are often severe.

Some of the advantages pertinent to petroleum production are shown in the table of comparisons. It is not practical to cite specific figures in comparing properties, since these may vary greatly according to the particular compound. Where necessary, one quality may be improved at the expense of another and in no case, either with natural or synethetic rubber, can all of the most favorable characteristics be obtained in a single compound. In the properties listed, comparisons have been based both on average compounds and on the ultimate that might be achieved in any one direction, where necessary.

| | NATURAL RUBBER | HYCAR-OR |
|---|---|---|
| Resistance to swelling and deterioration in oil & gasoline | Poor | Excellent |
| Resistance to Aromatic Hydrocarbons | Poor | Good |
| Resistance to abrasion | Good | Excellent |
| Heat resistance | Good | Excellent |
| Resistance to permanent set | Excellent | Very good |
| Resistance to cold flow | Good | Excellent |
| Resistance to tear | Excellent | Good |
| Resistance to aging | Good | Excellent |
| Resistance to water absorption | Fair | Excellent |
| Resistance to gas diffusion | Fair | Excellent |

There are several forms or types of Hycar, not all of them oil-resistant. A typical example of an "oil soluble" Hycar is one which has high dielectric strength and is proving of great value in the electrical insulation field. In a gasoline engine ignition cable the actual insulation might be made from Hycar OS, while the outer cover could be made from Hycar OR, to resist the gasoline, oil and grease that would undoubtedly come in contact with it.

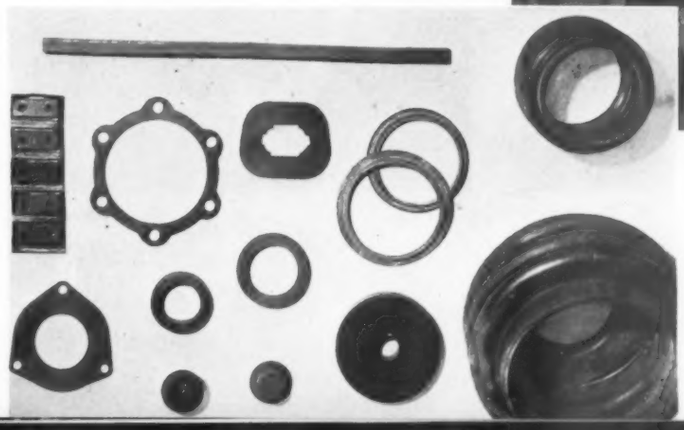
The versatility of Hycar synthetics in these uses in the petroleum industry has not been generally realized, due mainly to the concentrated attention upon their uses in war production. It is not too soon, however, to give serious attention to this. The applications are many, and they are increasing in proportion to our increased understanding of the nature and potentialities of these materials. The ability of Hycar to fill a wide range of specifications is at once its most valuable asset to the petroleum industry. The compounding of Hycar will give products ranging from soft resilient material to a bone hard Hycar with a tensile strength in excess of 10,000 pounds per sq. inch. This compounding technology is basically the same as for natural rubber—that is, it is compounded with sulfur, carbon blacks and other ingredients to impart desired properties. The art of compounding synthetic rubber may well be said to be still in its infancy and greater things can confidently be expected. Constant research will not only serve to improve the basic material but also the manner in which it is made into useful articles.

Hose of all types can be made of Hycar synthetics. Due to the fact that hose in this field is in constant contact with oils, gasoline and greases, the oil resistant qualities of Hycar offer a basic reason for its use, both for tube and cover of the hose. Short runs of pipe can be replaced with this type of hose and flexible connections for oil lines may well be the rule. Synthetic gaskets and packing made from Hycar are already in wide use, and they will become increasingly used because of their oil and heat resisting qualities, plus their low compression set characteristics.

Great possibilities are present in the use of Hycar for valves, pistons, packings, lining, rotors, vanes and idlers in various types of pumps and compressors and many service difficulties will be avoided by the use of these new butadiene synthetics. This is particularly true where the lighter petroleum products such as kerosene, gasoline and liquefied petroleum gases must be handled. The ability of Hycar to resist salt water and abrasion makes it ideal for use in slush pump piston rubbers, for handling the mud and salt water encountered in drilling. It is also ideal for use in mud valves in this same type of service. Flexible couplings for drive shafts, transmission belts, linings for cable block sheaves and brake linings are other applications for Hycar that will help the petroleum industry solve many of its vexing production problems. Brake linings on stationary equipment in drilling operations are notable for their service troubles due to constant presence of oil and grease. Linings made of Hycar should prove very valuable in this service.

Whether on a drilling location, pipeline service, booster station, refinery, gasoline plant, bulk station, or retail station, Hycar will come to mean a great deal to oil men. It not only has the characteristics of rubber in its natural state but in addition possesses many new qualities that offer real answers to operating and production problems of the petroleum industry. Hycar is a synthetic which can be compounded to meet a given need, making available to the petroleum industry a "tailor made" product to fit many and various operating functions, the parts for which heretofore have been less dependable because of the service conditions under which they had to operate.

The petroleum industry has helped create the greater utility of Hycar; the industry has also brought great production benefits to itself through the versatile product. This new synthetic not only replaces the service of natural rubber but in many instances it replaces other products, with greater efficiency and economy as the result.



*Above: Placing tubing samples in autoclave for open steam curve. Left: Die-cut gaskets and miscellaneous molded and extruded items.*

# Foreign Oil Legion

*Fred H. Kay*

FRED H. KAY, vice president of Standard Vacuum Oil Company, died July 9 at his home in New York City. Born in Illinois, Mr. Kay attended the University of Chicago, and upon his graduation in 1907 went with the United States Geological Survey. In 1909 he was geologist for the Southern Pacific Railway and later became assistant state geologist for the Illinois State Geological Survey. In 1920 he joined the Sun Oil Company and remained there for five years as manager of their Venezuelan office. From there he went with the Pan American Petroleum and Transportation Company, later entered the service of Standard Oil Co., N. J., and in 1939 he joined the Standard Vacuum Oil Company and was made director in charge of exploration and production in May 1940. Two years later he was elected vice president of the company.

IN PURSUANCE of its general plan of decentralizing the administration of sectional matters and making its district offices more nearly autonomous the Petroleum Administration for War has appointed H. W. Dodge of the Texas Company as director of District 1 with headquarters in New York and W. W. Vandeveer, president of Allied Oil Company of Cleveland as director of District 2 with main offices in Chicago. Wirt Franklin who has been in charge of District 2 has been made a special field assistant to the Deputy Petroleum Administrator as expediter of exploratory drilling.

IN CONFORMITY with the retirement plan of the company, E. B. Reeser, who has been President of Barnsdall Oil Company for many years, retired at the close of business on July 31. The Board of Directors has elected James A. Dunn as President, to succeed Mr. Reeser. Mr. Dunn has been with the Barnsdall interests since T. N. Barnsdall was an independent operator, and since 1926 has been Vice-President and Secretary. Frank Braman, Assistant Secretary and Assistant Treasurer, has been elected to the office of Vice-President and Secretary, effective August 1, 1943. Two new offices have been created by the directors; a general manager of the Mid-Continent Division and a general manager of the California Division. Vice President Dale R. Snow of Tulsa, Okla., and Vice President William C. Whaley of Los Angeles, California, have been elected to these positions.

AT THE award of the Army-Navy "E" to the men and women of the Gustin-Bacon plant at Kansas City for "outstanding production of war materials" Rear Admiral Charlton paid a high tribute to the company and its products, saying that Fiberglas board had become standard equipment on all new naval construction and was being installed on older vessels to reduce the fire hazard

*Rear Admiral Alex M. Carlton (left) and Lt. Colonel MacLean (right) at the presentation of the Army-Navy "E" to the Gustin-Bacon Co.*

from enemy bombs or shells. He also praised the company's Rolagrip pipe couplings and said, "You should be very happy to know that your couplings are helping to speed the day of victory."

(*Continued on Page* 50)

*E. B. Reeser*

*H. W. Dodge*

*W. W. Vandeveer*

*James A. Dunn*

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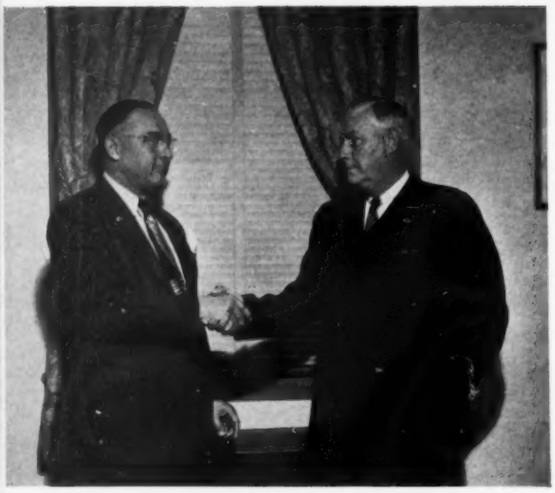
## Foreign Oil Legion



*Left, Alvin Zwerneman, and right, J. C. Axelson.*

ALVIN (DUTCH) ZWERNEMAN has resigned his position as vice president of the Axelson Company to accept a post with the Materials Division of the Office of Petroleum Administration for War. Mr. Zwerneman's appointment is the result of a special meeting of the Petroleum Equipment Dealers Association held sometime ago in Dallas at which a resolution was adopted requesting that a special section be created in the office of the Director of Materials to deal with the needs and problems of petroleum equipment manufacturers and suppliers. In speaking of Mr. Zwerneman's new responsibility, J. C. Axelson, president of the company said: "We are sure that Dutch will acquit himself with credit in this particular work and will be of great assistance to all manufacturers to whom a source of raw materials continues to be a problem."

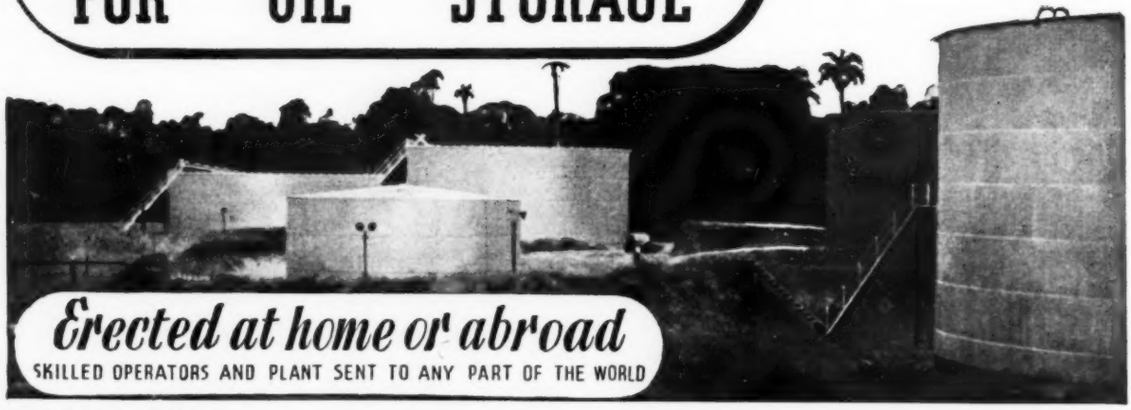
WALLACE D. WILSON, president of Wilson Supply Company has announced the formation of Wilson Foundry and Machine Company under his presidency. The new company has purchased the properties of the J. D. Nixon Company and will manufacture the Nixon Surface Control Gas-Lift system and other oil field specialties heretofore produced under the former ownership. Sales of all their products will be handled by the Wilson Supply Company.

J. R. (JACK) CUNNINGHAM who joined the Continental Oil Company 27 years ago as an office boy has been named assistant general sales manager of the company. From his start at the bottom of the ladder, Mr. Cunningham has served successively in the accounting department of the company, in the order and distribution section of the traffic department, as chief clerk of that section, as assistant on the general office sales staff and since 1937 as assistant manager of sales administration.

COLONEL C. G. IRISH, U. S. Army, is now with the forces abroad. Colonel Irish grew up in the oil business, and during his entire business career has been associated with the Standard Oil Company of New Jersey and the Atlantic Refining Company. For the past 23 years he has lived in France, where he occupied a managerial position with the Standard Francaise des Petroles, in which Company are grouped the French interests of Standard Oil of New Jersey, Gulf and Atlantic.

*Colonel C. G. Irish*


OXLEY *welded* TANKS FOR OIL STORAGE




TANKS ERECTED IN TRINIDAD . . .
One tank 114′ 6″ diam. × 38′ 6″ deep. Two tanks 80′ diam. × 42′ deep. Four tanks 50′ diam. × 40′ deep. Three tanks 9′ diam. × 30′ long. Twenty tanks 118′ diam. × 41′ 6″ deep. Five tanks 70′ diam. × 37′ deep. Two tanks 70′ diam. × 35′ deep.

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The illustration shows a group of Oxley Arc Welded Oil Storage Tanks erected in Trinidad, B.W.I. We are specialists in the design, manufacture and erection of tanks for the storage of petroleum, oil, etc., and have erected tanks up to 152′ 6″ diameter × 40′ 0″ deep. Our operators and plant are sent to any part of the world. A recent Trinidad contract included the cutting down of a riveted tank 114′ 0″ diameter, and re-erecting as a welded tank 30 miles from the original site. The seams were welded instead of riveted, allowing the depth of the tank to be increased from 34′ 4″ to 38′ 6″.

During the last few years we have erected a considerable number of welded oil storage tanks in Trinidad, a recent contract including 20 tanks 118′ 0″ diameter × 41′ 6″ deep.

O.E.

*FOUNTAINS ABBEY, NIDDERDALE, YORKSHIRE*

*According to a myth which has almost become history, Friar Tuck was a friar of Fountains : it was near here that he and Robin Hood fought each other to a standstill, and such a good time was had by all that the Friar joined the Sherwood Foresters.*

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Eventually that power was dissolved, but the Abbey itself remains ; and now, by a trick of history, is silent witness to an immense revival of farming in all the broad acres which surround it.

But it is more than history in stone, it is reminder as well as tradition. Here in our own shire is a grand object-lesson in craftsmanship and durability, reminding us to build worthily when we may. If for peace, civilised man digs or builds or writes as those Cistercian friars did ; that is, because he wills. If for war, he does those things because he must, but his real reason for doing the second is that he may return to doing the first.

We ourselves work neither on the soil, nor in stone, nor on vellum ; our medium is metal. Wartime has made it precious metal. When all industry is free to turn to reconstruction the demand for Transport will be enormous, and because bulk transport is logically established as the cheapest and safest means of carrying supplies of petroleum and oils, the demand for Butterfield Road Tanks will be heavier than ever before.

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## Synthetic Rubber Program

(*Continued from Page* 33)

rubberlike qualities of the product become even more apparent. The curds of coagulated material and, later, the strips of compressed "rubber"—which are cut and packed in cartons for shipment to the rubber fabrication plants—closely resemble natural rubber in its earlier stages of processing.

Fortunately for the rubber fabrication plants, machinery used to fabricate synthetic rubber is identical with that used for many years in the fabrication of natural rubber. The production of large quantities of the synthetic product might well have been a hopeless problem had the rubber companies been forced to design new plants and use new equipment for the fabrication of synthetic materials.

According to tire engineers of the B. F. Goodrich Co., some time is lost at present because large scale production of synthetic rubber has been going on for only a relatively short period, "whereas we have been working with natural rubber for several generations". The fabrication experts hope to cut this time loss, however, after the first of the year.

Temperatures must be watched more closely during the fabrication of synthetic rubber, the Goodrich Company explains, but they expect to lick this problem and eliminate the delay "with a little more experience". Another time-lag has been experienced in masticating the raw synthetic product, that is, during the operation of milling the rubber and turning it into tire stock and sheets for fabrication into various rubber products. But, as in the case of the 100 octane gasoline production program and many another war industry requiring extraordinary concentration upon new engineering enigmas—these early stumbling-blocks are being rapidly eliminated.

One real problem faces the rubber companies, however. Virtually all of the tire-making capacity in this country is presently tied up in making tires for the armed forces. If Rubber Director Jeffers' order for 30,000,000 civilian tires is to be carried out, civilian requirements will have to be superimposed on this capacity. Since there is little possibility that military tire requirements will drop, additional fabricating plant capacity will have to be constructed. Plans for new machinery and for new plants in various parts of the country are already under study.

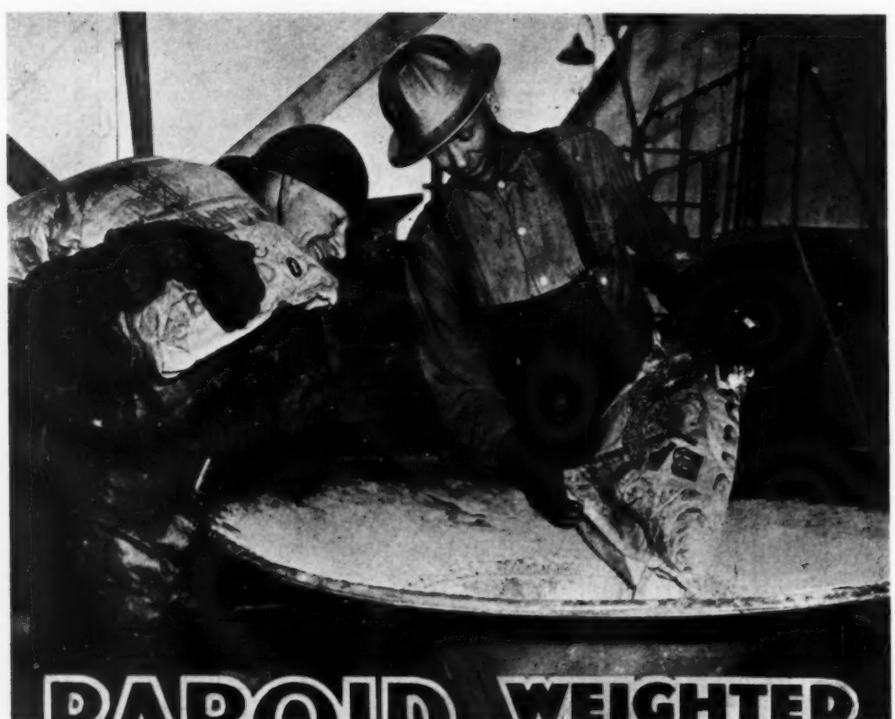
Post-war possibilities for an American synthetic rubber industry? This opens an intriguing field of speculation.

It is generally agreed that the real answer to the question will be weighted down with international politics, as well as a very important bone of contention between American industry and the United States Government.

British-Dutch control over natural rubber sources and prices may be maintained, or may be broken, largely dependent upon what concessions may be made after the war by the United States. The two great "rubber nations" had a very large stake in their vast rubber plantations in Polynesia and very naturally may resist the continuance of the synthetic rubber industry in any large degree in the biggest market for rubber in the world.

Complications in the post-war rehabilitation of the natural rubber industry are a foregone conclusion. One important factor, it is argued, will be labor, since the arrival of troops from America, Great Britain, and other United Nations in remote areas of the Pacific already has given the natives a sense of money-values which was totally lacking before the war.

Talk that natural rubber will drop from its pre-war price of approximately 21 cents per pound



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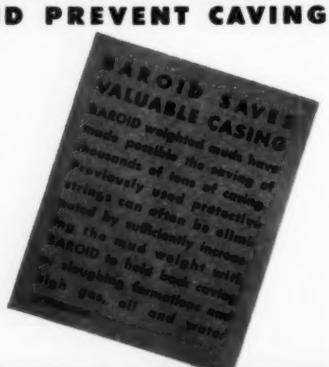


PATENT LICENSES on a royalty basis, unrestricted as to sources of supply of materials, will be granted to responsible oil companies and operators to practice the inventions of any and/or all of United States Patents Nos. 1,807,082; 1,991,637; 2,214,674; 2,294,877 and further improvements thereof. Applications for such licenses should be made to the Los Angeles office.

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should be discounted, some experts say, if labor in the rubber-raising areas becomes aware of the fact that it has been exploited in the past.

On the other hand, America will be left with huge and costly installations which will have little value if the production of synthetic is abandoned.

Some of the "specialty" rubbers, which have proven superior to the natural product for certain uses, will endure, the experts say. Neoprene and Buna N have been placed in this category. Butyl may remain, because of its adaptability for tubes, life rafts and other inflated goods.

A very vital factor in the post-war existence of synthetic rubber is the extent of damage done to the rubber plantations seized by the Japanese. If the jungle has been permitted by the Japs to "go back in", rubber experts see years ahead where America will be forced to rely on synthetics. It is also possible that, although the Japanese may have spared many rubber plantations for selfish reasons, they will destroy these properties when the day arrives for the Allies to try to snatch them back.

Much also depends on the stand taken by the sponsors of rubber-from-alcohol. This element has strong farm-belt representation in Congress, is traditionally opposed to the petroleum industry and can be depended upon to raise a hue and cry about depletion of U. S. oil reserves by greedy capitalists.

The alcohol people themselves will have a very large stake in the synthetic rubber industry, when the war is over. It will be one way of disposing of surplus grain crops, providing a surplus exists when the war is over and when the starved populations of the war-weary world have been fed, and providing the distilling industry does not demand the grain that might be used for the distillation of whisky.

One champion of synthetic rubber is Rubber Director Jeffers, who firmly advocates continuance of synthetic rubber production by private industry after the war. Diametrically opposed, is Vice President Henry A Wallace, who would like to see the bulk of the industry scrapped when peace arrives and a return to the use of natural rubber.

The fate of the industry cannot be forecast. The post-war presidential elections may play an important part in any decision affecting the extent to which the synthetic product will be manufactured after the duration. An administration favorable to private initiative could be expected, of course, to foster continuance of present manufacturing operations.

Regardless of what can be expected in the future, and regardless of earlier indecisions and possible mistakes on the part of the government in expediting the program, the rubber needs of the military machine now are being met; production is increasing daily and all signs point to a self-sufficiency in rubber which was not dreamed of before Pearl Harbor.

The Office of the Rubber Director, and affiliated Government agencies handling the program, such as the Defense Plant Corporation and Rubber Reserve Company, have earned the sincere gratitude of a public which knows that the all-important needs of the armed forces for rubber are being cared for and that there is an excellent chance civilian requirements soon will be forthcoming.

The petroleum industry, the chemical, rubber and alcohol industries, are no less deserving of praise for a magnificent job accomplished in the face of seemingly insuperable obstacles, and full credit should go to the engineers, chemists and technicians employed by the government and by industry to see the program through.


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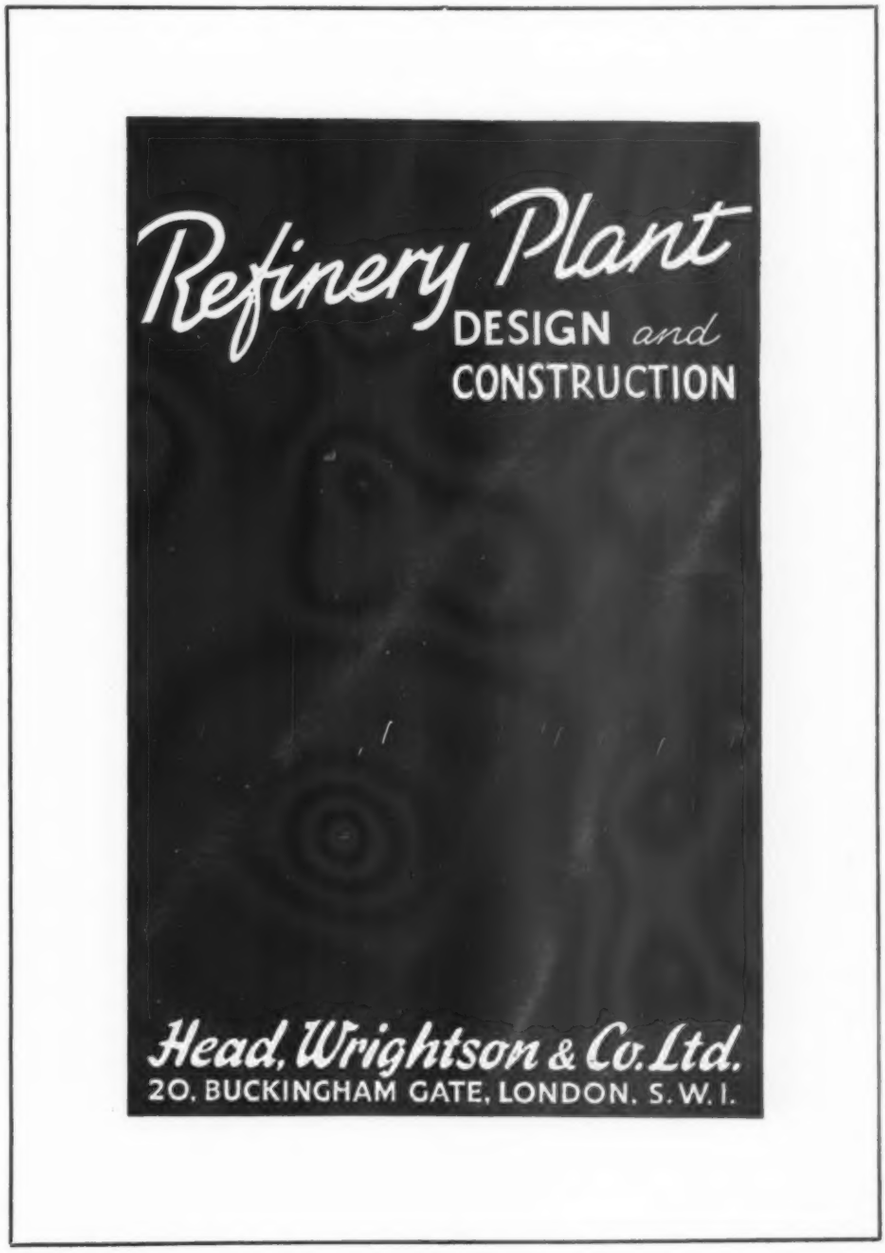

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*Given under my hand and seal on* June 9, 19 43

Henry Morgenthau Jr.
SECRETARY OF THE TREASURY

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*The Management Publication of the International Petroleum Industry*
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Thank you, Mr. Morgenthau, for the accolade - for the tap of the sword on the shoulder! But may I say that what we have done is only what millions of other good Americans are quietly doing - helping in every way, within our limitations, to win this War.

Thos Palmer.
Publisher, WORLD PETROLEUM

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**2** Condition of flumes or distributing system.

**3** Analysis of water loading for optimum performance.

**4** Analysis of net effect of recycling.

**5** Condition of stair treads, ladder rungs and hand rails.

**6** General condition of structure.

**7** Condition of mechanical equipment (motors, fans, gears, flexible couplings, etc.)

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SINCE 1890

## Relation of Petroleum to War

(*Continued from Page* 43)

of Germany's synthetic petroleum industry was located originally in the industrial area of the Ruhr-Rhine region. The intensive bombing attack directed against this whole territory during the past year has caused widespread destruction and in all probability has damaged some of these establishments and interrupted their operation if they have not been put out of existence. Plants of later construction located in eastern Germany and Czechoslovakia have not been exposed to the same hazards, but it is improbable that the total output is in excess of 4,000,000 tons if indeed it equals that figure.

Whether the oil resources of the Axis are 12,000,000 tons or something more or less does not alter the fundamental fact that they are not sufficient to cope with the power that is ranged against them and that they are not capable of enlargement. That would be possible only if the Axis forces could break through the circle that has been drawn around them. This they have failed to do in two desperate drives directed eastward toward the great oil supplies lying in that direction and the possibility of success for any such effort appears to have passed.

The pattern of the war is now definitely set. It involves the use of air power in ever increasing volume to crumble defenses and to provide cover for the men and machines whose task will be to overcome resistance based on surface conflict on land or sea. Since the machines which will play a decisive part in the struggle all depend upon petroleum products of one kind or another oil will prove the determining factor in the outcome which is bound to favor the side possessing and utilizing most effectively the greater oil resources. The failure of the Nazi drive to the East ended the Axis hope of attaining equality in this respect. Allied operations in the Mediterranean theatre point the way to final Axis defeat through the might of oil-powered weapons of attack.

## War Emergency Pipe Line Completed

(*Continued from Page* 28)

Steel Tank Construction Co., Dallas, Tex., dismantling and erecting tanks.

C. Hobson Dunn, Dallas, Tex., hauling and stringing pipe.

Parkhill Truck Co., Tulsa, Okla., hauling and stringing pipe.

J. L. Cox & Son, Raytown, Mo., hauling and stringing pipe.

J. R. Vandaveer, Neodosha, Kansas, hauling and stringing pipe.

Suppliers of equipment included the following:

National Tube Co., Pittsburgh, Pa., pipe.

Youngstown Sheet & Tube Co., Youngstown, Ohio, pipe.

A. O. Smith Corp., Milwaukee, Wis., pipe.

Republic Steel Corp., Cleveland, Ohio, pipe.

Jones & Laughlin, Pittsburgh, Pa., pipe.

General Electric Co., Schenectady, N. Y., electrical equipment.

Westinghouse Electric & Mfg. Co., Pittsburgh, Pa., electrical equipment.

Allis-Chalmers Co., Milwaukee, Wis., centrifugal pumps.

Ingersoll Rand Co., New York, centrifugal pumps.

Wagner Electric Co., St. Louis, Mo., transformers.

Moloney Electric Co., St. Louis, Mo., transformers.

Barrett Division of Allied Chemical & Dye Co., New York, pipeline enamel.

Wailes-Dove-Hermiston, Westfield, N. J., pipeline enamel.

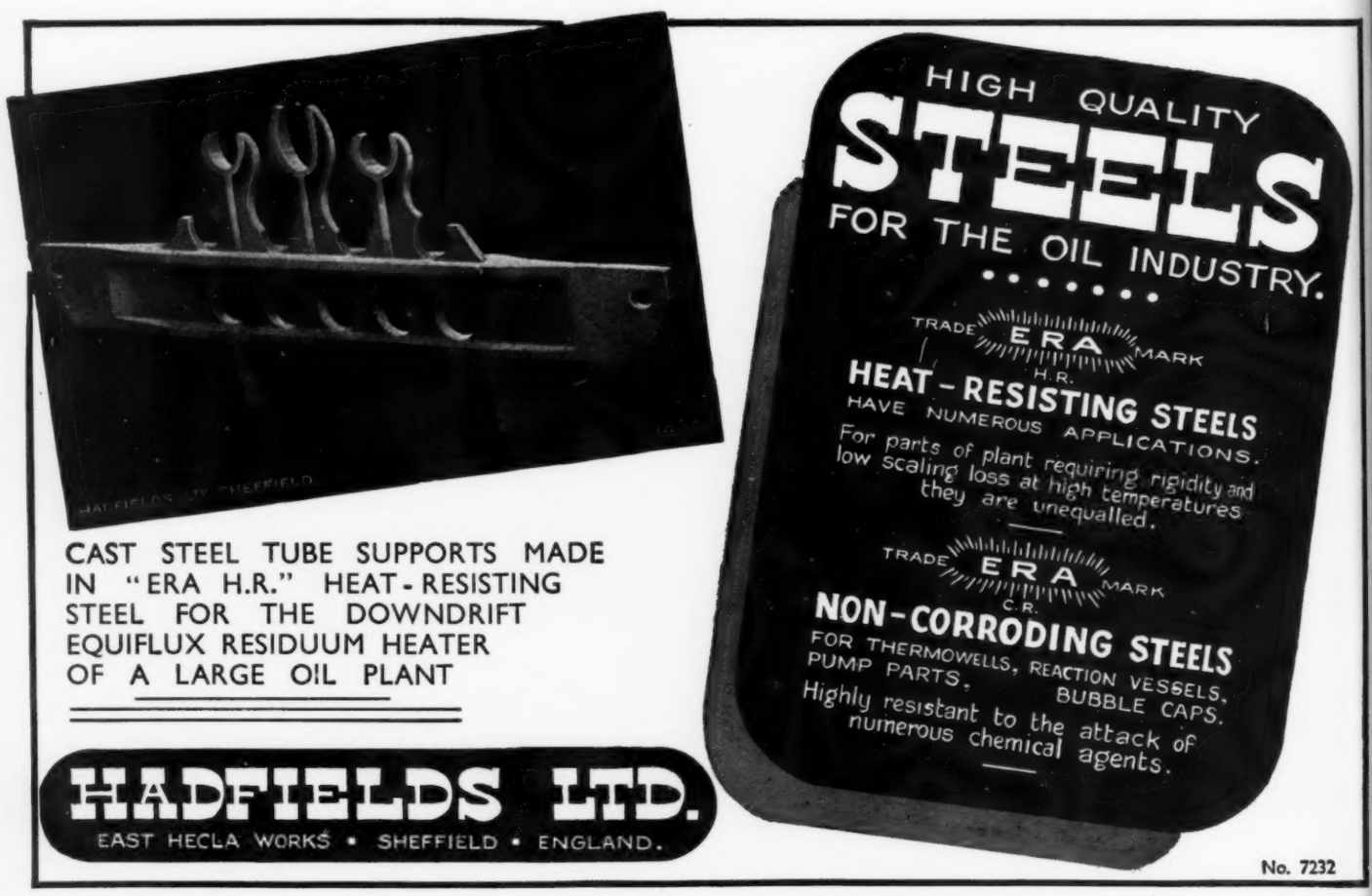
Reilly Tar & Chemical Co., Indianapolis, Ind., pipeline enamel.

Johns-Manville Corp., New York, saturated asbestos felt.

The Philip Carey Co., Cincinnati, Ohio, saturated asbestos felt.

Darling Valve Manufacturing Co., Williamsport, Pa., gate valves.

Westcott Valve Co., East St. Louis, Ill., valves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